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CAVE3 — A General Transient Heat Transfer Computer Code Utilizing Eigenvectors and Eigenvalues

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National Aeronautics and
Space Administration

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28 February 1978

Gentlemen:

Enclosed is a corrected copy of "CAVE3-A General Transient Heat Transfer Computer Code Utilizing Eigenvector and Eigenvalues". The previous copy of the report you received had an erroneous report and contract number printed on the cover. Please discard it and replace it with this corrected copy. Please accept our apologies for any inconveniences.

Sincerely,

GRUMMAN AEROSPACE CORPORATION

Dr. Kenneth A. Rathjen

Joseph V. Palmieri

Enc.

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16. Abstract

This report describes a digital computer code CAVE3 (Conduction Analysis Via Eigenvalues for Three Dimensional Geometries) which provides a convenient and economical tool for predicting the transient temperature response of structures. This code is an extension of the work done under contract NAS1-13655 for two-dimensional geometries. CAVE3 is written in FORTRAN IV and is operational on both the IBM 370/165 and CDC 6600 computers.

The method of solution is a hybrid analytical-numerical technique which utilizes eigenvalues (thermal frequencies) and eigenvectors (thermal mode vectors). The method is inherently stable, permitting large time steps even with the best of conductors with the finest of mesh sizes which can provide a factor-of-five reduction in machine time compared to conventional explicit finite difference methods when structures with small time constants are analyzed over long time periods. This code will find utility in analyzing hypersonic missile and aircraft structures which fall naturally into this class.

The code is a completely general one in that problems involving any geometry, boundary conditions and materials can be analyzed. This is made possible by requiring the user to establish the thermal network, e.g., node capacitances, conductances between nodes, etc. Dynamic storage allocation is used to minimize core storage requirements.

This report is primarily a user's manual for the CAVE3 code. Input and output formats are presented and explained. Sample problems are included which illustrate the usage of the code as well as establish the validity and accuracy of the method.

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SUMMARY

This report describes a digital computer code CAVE3 (Conduction Analysis Via Eigenvalues for Three Dimensional Geometries) which provides a convenient and economical tool for predicting the transient temperature response of structures. This code is an extension of the work done under contract NAS1-13655 for two-dimensional geometries. CAVE3 is written in FORTRAN IV and is operational on both the IBM 370/165 and CDC 6600 computers.

The method of solution is a hybrid analytical-numerical technique which utilizes eigenvalues (thermal frequencies) and eigenvectors (thermal mode vectors). The method is inherently stable, permitting large time steps even with the best of conductors with the finest of mesh sizes, which can provide a factor-of-five reduction in machine time compared to conventional explicit finite difference methods when structures with small time constants are analyzed over long time periods. This code will find utility in analyzing hypersonic missile and aircraft structures which fall naturally into this class.

The code is a completely general one in that problems involving any geometry, boundary conditions and materials can be analyzed. This is made possible by requiring the user to establish the thermal network, e.g., node capacitances, conductances between nodes, etc. Dynamic storage allocation is used to minimize core storage requirements.

This report is primarily a user's manual for the CAVE3 code. Input and output formats are presented and explained. Sample problems are included which illustrate the usage of the code as well as establish the validity and accuracy of the method.

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Section 1

INTRODUCTION

The computer code CAVE3 (Conduction Analysis Via Eigenvalues for Three Dimensional Geometries) provides a convenient and economical tool for predicting the transient temperature response of structures. It will find special utility in the analysis of thermal protection systems for hypersonic missiles and aircraft where the flight trajectory time is large in comparison to the time constants of the structures.

The method employed by CAVE3 to solve the partial differential heat conduction equation is a hybrid analytical-numerical (HAN) technique which was developed under a previous NASA contract NAS1-13655 (Ref. 1).

Mr. James L. Hunt, of the High Speed Aerodynamics Division, Langley Research Center, Virginia, served as the NASA technical monitor for that program.

In the HAN method, spatial deviatives are replaced by appropriate finite difference representations and the temporal derivatives are retained as ordinary derivatives. In effect the problem is subdivided into a number of uniform temperature systems or nodes that are coupled and changing in temperature. The problem is thereby specified by a set of first order, linear, ordinary differential equations whose solution is expressed in terms of eigenvectors (thermal mode vectors for the system) and eigenvalues (thermal frequencies of the system). The complete solution for a system involving N nodes contains N eigenvalues and N eigenvectors. The determination of all N eigenvalues and eigenvectors involves formidable computations for typical heat transfer problems involving hundreds of nodes - however the accuracy requirements of most problems do not require the determination of all N eigenvalues and eigenvectors. In fact, a small number say 10 or so are sufficient when the heat flux response is contained in the first few thermal modes (characteristic of materials with high thermal diffusivity) or if the response for a large number of time increments is required, which is precisely the situation in predicting the temperatures throughout the flight trajectory of a hypersonic vehicle. A reduction by a factor of five in computer time can be expected over conventional explicit finite difference codes for typical flight trajectory analyses. The savings in computer time is due to the HAN method

being inherently stable and, therefore, permitting large time steps in comparison to an explicit algorithm.

This report is basically a user's manual for CAVE3. The next section discusses the overall operation and running of CAVE3 while Section 3 describes the input data format. Sections 4 and 5 present two sample problems provided by the contract monitor. These problems are used to illustrate the input data and output of CAVE3 and to establish the validity and accuracy of the code. Section 6 provides the programmer oriented documentation of CAVE3, i.e., list of subroutines, variables and logic diagrams.

Mr. Charles B. Johnson, of the High Speed Aerodynamics Division, Langley Research Center, Virginia, served as the NASA technical monitor for the program.

At Grumman, the contract was administered by the Advanced Development office, under Fred Berger, Manager of Advanced Development System Engineering. The Study Manager was Dr. Kenneth A. Rathjen. Mr. Joseph V. Palmieri developed much of the code and Mr. Michael J. Rossi developed the matrix routines.

Section 2

DESCRIPTION OF CAVE3 CODE OPERATION

This section provides an overview of the CAVE3 code capabilities, method of solution and input/output.

CAVE3 has been designed to be a completely general digital computer code for operation on the CDC 6600 and IBM 370/165 computers. Operation of CAVE3 requires the following type of information from the user:

- Initial temperatures of nodes
- Capacitance (mass times specific heat) of each node
- Conductance (and convection) links between nodes
- Radiation links between nodes
- Heat generated at a node
- Boundary conditions (e.g. adiabatic wall temperature or recovery temperature and convective heat transfer coefficient)
- Thermal properties as a function of temperature
- Initial and final time
- Time steps (which can be variable)

The user may assign any node numbering system desired; CAVE3 establishes a node labeling array that is packed to ensure efficient matrix operations. The input for CAVE3 has been designed to be totally generalized and options have been provided to minimize the amount of input. The data is structured in blocks and resides on one data file. A detailed description of the input is provided in Section 3.

The user, via input, establishes the overall core size available. CAVE3 dynamically allocates storage for the individual arrays based on the data input. In this fashion the user does not pay for excess overhead by executing a program designed for a large scale problem with fixed storage when running a smaller problem. The code is designed so that the data storage is set-up and maintained in the main program and the program flow is controlled by subroutine CAVE3. The program is modular in structure which aids the user to understand the logic and make changes if desired.

A description of each subroutine and its specific task, along with flow charts, is presented in Section 6.

The main advantage of CAVE3 over other general thermal analyzer codes is in execution time. CAVE3 will prove economical in solving transient heat conduction problems involving structures with time constants that are small compared to the time period of interest (e.g. flight trajectory). The method employed in CAVE3 is a hybrid analytical-numerical technique that is inherently stable permitting large time steps in comparison to explicit finite difference methods. It is noted that there is a significant amount of computer time required to determine the eigenvectors and eigenvalues of the solution, and therefore the method is not advantageous compared to conventional explicit schemes for problems involving a short time period (e.g. total time of interest on the order of 100 times the maximum permissible time step).

A detailed description of the method is presented in Ref. (1) and therefore only a brief overview is presented here. The transient heat conduction problem being solved is characterized by the following system of n first-order linear differential equations with constant coefficients

$$C_i \frac{dT_i}{dt} = \sum_j K_{ij} (T_j - T_i) + H_i (T_{AW,\,i} - T_i) + \dot{Q}_i \qquad i = 1,n \qquad \text{Eq. (1)}$$

where C_i = thermal capacitance of node i

K_{ij} = conductive coupling between nodes i and j

T_i = temperature of node i

T_j = temperature of node j which is adjacent to node i

H_i = convective coupling between node i and the fluid (for interior nodes $H_i = 0$)

t = time

$T_{AW,i}$ = adiabatic wall temperature of the fluid in contact with node i

$\dot{Q}_i$ = heat generated at node i

There are n such coupled differential equations, one for each of the n nodes.
It is noted that radiation between nodes is considered via a linearization process described in Appendix C of Ref. (1) which leads to modified conductive and/or convective couplings.

The system of equations given in Eq. (1) has the following exact solution for a particular time-subinterval (Appendix F of Ref. (1) gives the details):

$$T_i = T_{\infty_i} + \sum_{j=1}^{n} c_{ij} \exp(\lambda_j t) \qquad \text{Eq. (2)}$$

where

T_i = temperature at node i at time t seconds into the time subinterval

T_{∞_i} = steady-state temperature at node i for the particular time subinterval

c_{ij} = constants that depend on the T_{∞_i}, a set of eigenvectors of a matrix A, and the temperatures of the nodes at the start of the time subinterval

λ_j = the eigenvalues of a matrix A

t = time into the particular time subinterval. If τ represents the time in the flight trajectory, and if τ_s and τ_e represent the time at the start and end of a time subinterval, then the following relationships hold:

$$0 \leq t \leq \tau_e - \tau_s \text{ and } \tau = \tau_s + t \text{ for } \tau_s \leq t \leq \tau_e$$

A = symmetric matrix whose elements depend on the C_i, K_{ij} and H_i of Eq. (1). (Refer to Appendixes A and F of Ref. (1).)

Considering a thermal network with n nodes, there are then n eigenvalues and eigenvectors to be determined and used in Eq. (2). Considerable machine time can be saved by calculating only those eigenvalues and eigenvectors that are "significant" or "dominant". This was noted very aptly by Maise and Rossi in NASA CR-2435 and used by them in the CAPE code for the inverse heat transfer problem of finding the boundary conditions given the temperature history, and it was used in Ref. (1). When the series in Eq. (2) is truncated to the "dominant" terms, we obtain:

$$T_i = T_{\infty_i} + \sum_{j=1}^{ne} c_{ij} \exp(\lambda_j t) \qquad \text{Eq. (3)}$$

where ne is a number substantially less than n. It represents the number of dominant eigenvalues and eigenvectors that will be found and utilized by the code. This is an input number decided upon by the user. Appendix A of Ref. (1) discusses the effect of ne on solution accuracy.

It may be interesting to digress for a moment to note that the usual thermal analyzers take equation (1) a step further and replace the ordinary derivative $\frac{dT_i}{dt}$ with a finite difference approximation. Depending on the form of the approximation either an explicit or implicit algorithm is obtained. In the common explicit and implicit formulations, the T_i's and T_j's are taken to be constant during the time step interval. In the current HAN method, the ordinary derivative is retained and the T_i's and T_j's are treated as time-dependent variables in Eq. (1). This leads to a more accurate solution with no limitation on the time step from a stability standpoint. However, in solving Eq. (1), the HAN method treats the C_i, K_{ij}, H_i and $T_{AW,i}$ as constants. This is necessary, as discussed in Appendix E of Ref. (1), for an eigenvalue solution to exist. The technique used within CAVE3 to handle variations in these parameters is to subdivide the total time interval (e.g., the flight trajectory) and take these parameters to be piecewise constant within each time subinterval.

Thus, the single problem of determining the temperature distribution in the structure where the boundary conditions are varying is solved by considering a number of subproblems where the boundary conditions are piecewise constant. These subproblems are interconnected in that the temperature at the end of one time subinterval becomes the initial temperature for the next time subinterval. It should be noted that the time subintervals, or time steps in the HAN method, are typically of the order of seconds or tens of seconds which is probably 100 to 1000 times larger than is permissible with the explicit method.

CAVE3 uses the convective coefficient and adiabatic wall temperatures at the beginning of the time interval for the entire time interval. Therefore in selecting the time subintervals, the user should be guided by the variation in the boundary conditions with particular concern for abrupt changes that affect the convective heating. For those problems in which the temperature dependency of the material properties plays a dominant role for some reason, or if radiation heat transfer is of great importance, a second run with smaller subintervals should be made to determine the effect of subinterval selection on the predicted temperatures.

The problem solution is accomplished in CAVE3 using the following sequence:

1. Storage requirements for the various arrays are determined and allocated.
2. Initial conditions are printed out.

Then for each time step the following are done:

3. Using the temperature distribution at the start of the time step, the thermal properties of the materials are determined, followed by the capacitances and conductances for the network. This step is not exercised if the material properties are independent of temperature.

4. The convective heat transfer and conduction couplings are then modified to account for radiation if it is being considered. Appendix C of Ref. (1) gives the details of the linearized treatment that is given to the radiation heat transfer.

5. Set up a matrix A in compact form which depends on the C_i, K_{ij} and H_i of Eq. (1) (Refer to Appendix F of Ref. (1).)

6. Obtain the ne dominant eigenvectors and eigenvalues of matrix A using Jennings[2] method of simultaneous vector iteration.

7. Determine the steady-state solution to Eq. (1).

8. Calculate the c_{ij} of Eq. (3) for i = 1, 2, . . . , n and j = 1, 2, . . . , ne.

9. Calculate the temperatures of the nodes at the end of the time subinterval using Eq. (3).

10. Set the initial temperatures for the next time subinterval equal to the final temperature of the present subinterval. Increment time.

11. Print temperatures.

12. Repeat steps 3 through 11 until the final time has been reached. The solution is then completed.

The following sections describe in detail the input data format for CAVE3 and two sample problems which will enable the reader to use CAVE3.

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Section 3

INPUT DATA FORMAT

The input to CAVE3 consists of one data file containing 3 control cards, 4 title cards and 9 distinct blocks of information. The unit input is general in that any set of consistent units can be used. The general format is displayed in Figure 3-1 and a more detailed set of descriptions is presented in Figure 3-2.

First Control Card:

This card consists of 11 variables describing the storage size, the degree of accuracy and the input output options. The variable NUMBND indicates the number of boundary nodes, NUMITR, the number of iterated nodes, NUMCON, the number of conductors, which includes conduction and convection links, NUMRAD, indicates the number of radiators, NUMNOD, the highest node number, NUMFLX, number of heat fluxes. These variables are used to determine the size of the data array. Care should be taken to minimize the size of each variable to truly represent the problem to be solved for excess size will cause a need for excessive core storage and increase the running time. Variable NSTR, is a storage parameter which indicates the size of the problem. The program will compute the value during execution and output the input value versus the computed value, thereby allowing the user to modify NSTR to the proper value. NEVALU is used to indicate the number of eigenvalues to be used to solve the problem. The higher the number of eigenvalues used the more accurate the solution and the longer the execution time. The user should investigate the proper size of NEVALU and minimize its size. Generally the smaller the size problem the smaller the number of eigenvalues needed to obtain the proper solution. IDIAG, is the diagnostic flag. If the user wants a more detailed output indicating the steady state solution at each time step and the dominant eigenvectors the user should set IDIAG equal to 1. Leaving IDIAG blank or setting it to 0 indicates the user wants only the temperature time history written out. IFLUX is also an output flag. If IFLUX is equal to one it indicates that the user wants the cumulative fluxes printed out for each node at each time step; a zero indicates no fluxes should be written out.

Title Block:

The user can use four cards to describe the problem (four cards are required). The title block will be printed out in the output.

Second Control Card:

This card consists of two variables KODE and NMTRIC. KODE should be left blank. NMTRIC is a flag indicating the units of input; 0 indicating degrees Fahrenheit; 1, degrees Rankine; 2, degrees Centigrade and 3, degrees Kelvin.

Third Control Card:

This card consists of variables KODE, TIME, DTIME, FTIME, and SIG. KODE again should be left blank, TIME indicates the initial time, DTIME indicates the time step, FTIME, the final time and SIG the Stefan-Boltzmann constant. If SIG is left blank or set to zero it indicates that the Stefan-Boltzmann constant has been folded into the radiation couplings.

Initial Temperature Block for Iterated Nodes:

This block of data establishes the initial temperature values for each of the iterated nodes. Variables II and JJ, the multiple parameter input are used to condense the input where the user numbering scheme allows. This Multiple Parameter Input option is explained at the end of this section.

Temperature Block for Boundary and/or Specified Temperature Nodes:

This block of data consists of the temperature values of boundary nodes and/or nodes within the structure with specified temperatures. The multiple parameter input is available to minimize the input. These values can be made to vary with time by using the proper table format (discussed in Table Block).

Capacitance Block

Within this block the node thermal capacitance (mass times specific heat) is stored in the CAP(N) array for each node N. Again the multiple parameter option is available.

Conductance Block

The nodal conductance (and convection) values are contained in this block of data. The program requires a conductance sequence number N, the two node numbers I and J that are linked and the conductance value COND(N). The conductance value represents

an overall UA and therefore is associated with both conduction and convection links. Note the link need only be established in one direction i.e., if a conductor is input from node 6 to 12 it need not be listed again from 12 to 6.

Radiation Coupling Block

The radiation links are stored in this block of data. Similar to the conductance block, N represents the radiation sequence number, followed by I and J the node numbers connected by the radiation link, followed by the radiation coupling value. (As with the conductor links it should only be input once.) This value can contain the Stefan-Boltzmann constant or can be computed without it, but the SIG flag must indicate which option the user selected.

Heat Source Block

The heat source or sinks are stored in this block. The heat source sequence number (N) should be input followed by (I) the number of the node to which the source is applied and $\dot{Q}(I)$, the heat source value.

Conductor Constant Block

This block contains the parameter $A/\Delta X$, the conductor constant. This parameter is used when adjusting the conductance to represent the effect of changing thermal properties. The symbol A represents the cross sectional area perpendicular to the flow of heat. The ΔX term represents the distance from the node center to the node boundary. The parameter is stored as a function of the conductor number it is associated with (N). DIS1(N) represents the value of the constant associated with the node from which the conductance is emanating from. DIS2(N) represents the value of the constant associated with node to which the conductance is emanating to. Figure 3-3 is presented to demonstrate the computation of the conductance term and the geometric positions of variables A and ΔX.

Table Block

The table format is simple and permits convenient manipulation. Tables are assigned consecutive table numbers according to their position in the input data array. Each table starts with a header card specifying the table dimensions, i.e., the number of values of the independent variable and the number of dependent variables, followed by a table index which indicates the type of table, and then an optional title. A list of table types and their descriptions are listed in Figure 3-2 in the Table Block section and explained below. The values of the independent variable are specified on the next

card. These values are listed consecutively, up to 7 per line as required. The dependent variables follow with all values of each variable being specified consecutively. The tables make no use of sequence numbers to identify variables or records. No blank record or delimeter is used at the end of a table; the next table or the 11100 record (to indicate the end of the table block) follows immediately.

The LFLAG index, as mentioned previously, is used to distinguish the use of each table. The table options are broken up in seven segments. The user has the option to vary: (1) the time step as a function of time (LFLAG equal to 1), (2) the boundary temperature with time (10000 < LFLAG < 20000), (3) heat sources or sinks with time (20000 < LFLAG < 30000), (4) conductance value versus temperature (30000 < LFLAG < 40000), (5) conductance value versus time (40000 < LFLAG < 50000), (6) capacitance value versus temperature (50000 < LFLAG < 60000) and (7) thermal properties versus temperature (LFLAG = 99999). In all cases except the first and last, LFLAG also related the node number, or conductor number with the changing parameter it was associated with i.e., if node 99 was a boundary node and its temperature was a function of time the user would have input a value of 10099 for LFLAG indicating boundary temperature (node number 10099-10000) was changing with time and at every new time step a new value would be extracted from the table. If the user wants to adjust the time step he must input in the first table the desired time steps as a function of increment. Note the first time step is set by the initial input in control card 3. An example would be if the user input an initial DTIME equal to .001 and wanted it increased by .001 four times. The user would have put in the first table of his input a L1 = 4, L2 = 1, and LFLAG = 1 followed by a card with the increments 1., 2., 3., and 4., and finally a card with .002, .003, .004, and .005. The program would have understood this to mean the first time step should be .001, the second .002, the third .003, the fourth .004 and the fifth .005. The final LFLAG segment is used when conductivity and/or specific heat are changing with temperature. This option assumes the first dependent variable input in the table is specific heat and the second the conductivity. When this table option is activated an additional block of information has to be input. That is a node table number correspondence table. A value must be entered for each node whose property changes with time and the table number associated with the properties of that node. If all iterated node properties are represented by a single table (same material), the user can set the variable J1(1)=0 and J2(1)=table number. The program will then automatically assign the table number stored in J2(1) to all nodes.

Termination Card:

The last data entry must be a 11100, card indicating data termination.

First Control Card

Title Block (4 cards)

Second Control Card

Third Control Card

Initial Temperature Block for Iterated Nodes

11100

Temperature Block for Boundary and/or Fixed Temperature Nodes

11100

Capacitance Block

11100

Conductance Block

11100

Radiator Block

11100

Heat Source Block

11100

Conductor Constant Block

11100

Table Block

11100

Node/Table Information

11100

Termination

Figure 3-1. General Data Format

First Control Card (1015)

NUMBND	=	Number of boundary nodes
NUMITR	=	Number of iterated nodes
NUMCON	=	Number of conductors
NUMRAD	=	Number of radiators
NUMNOD	=	Highest node number
NUMFLX	=	Number of fluxes
NSTR	=	Storage parameter
NEVALU	=	Number of eigenvalues
IDIAG	=	Diagnostic flag (0, no diagnostic; 1, diagnostics)
IFLUX	=	Flux option (0, fluxes not to be printed; 1, fluxes to be printed out)

Title Block

4 Title Cards (any format)

Second Control Card

KODE, NMTRIC (I5, 15X, I5)

KODE	=	0 or blank
NMTRIC	=	0, input in degrees Fahrenheit
	=	1, input in degrees Rankine
	=	2, input in degrees Centigrade
	=	3, input in degrees Kelvin

Figure 3-2. Detailed Input Description (Sheet 1 of 6)

Third Control Card

KODE, TIME, DTIME, FTIME, SIG (I5, 4E10.0)

KODE = 0 or blank

TIME = initial time

DTIME = computing interval

FTIME = end of computing time

SIG = Stefan-Boltzmann constant

Values for the Stefan-Boltzmann constant, in various units are given in the following table. It should be noted that if a zero is input or no Stefan-Boltzmann constant is input the program assumes it will be included in the radiation links.

Stefan-Boltzmann Constants

0.1714×10^{-8}	BTU/hr - sq. ft. - $^{o}R^{4}$
5.673×10^{-12}	Watts/sq. cm. - $^{o}K^{4}$
1.355×10^{-12}	Cal/sec - sq. cm. - $^{o}K^{4}$
5.669×10^{-5}	ergs/sec - sq. cm. - $^{o}K^{4}$

Initial Temperature Block for Iterated Nodes

KODE, N, T(N), II, JJ (2I5, E10.0, 2I5)

.

.

.

11100 (I5)

KODE = 0 or blank

N = node number

T (N) = node initial temperature

II = limit for multiple parameter input

JJ = spacing for multiple parameter input

Figure 3-2. Detailed Input Description (Sheet 2 of 6)

Temperature Block for Boundary and/or Fixed Temperature Nodes

KODE, N, T (N), II, JJ (2I5, E10.0, 2I5)

.

.

.

11100 (I5)

KODE = 0 or blank
N = node number
T (N) = boundary node temperature
II = limit for multiple parameter input
JJ = spacing for multiple parameter input

Capacitance Block (for iterated nodes)

KODE, N, CAP (N), II, JJ (2I5, E10.0, 2I5)

.

.

.

11100 (I5)

KODE = 0 or blank
N = node number
CAP (N) = node capacitance (mass x specific heat)
II = limit for multiple parameter input
JJ = spacing for multiple parameter input

Conductance Block

KODE, N, I, J, COND (N), II, JJ (4I5, E10.0, 2I5)

.

.

.

11100 (I5)

KODE = 0 or blank
N = conductance sequence number
I = first connected node number
J = second connected node number
COND (N) = conductance value (overall UA)
II = limit for multiple parameter input
JJ = spacing for multiple parameter input

Figure 3-2. Detailed Input Description (Sheet 3 of 6)

Radiation Coupling Block

KODE, N, I, J, RAD(N), II, JJ (4I5, E10.0, 2I5)

.

.

.

11100 (I5)

KODE = 0 or blank

N = radiation coupling sequence number

I = first connected node number

J = second connected node number

RAD(N) = radiation coupling value (Stefan-Boltzmann constant must be input either in the second control card or in each value for radiators)

II = limit for multiple parameter input

JJ = spacing for multiple parameter input

Heat Source Block

KODE, N, I, $\dot{Q}$(I) (3I5, E10.0)

.

.

.

11100 (I5)

KODE = 0 or blank

N = heat source sequence number

I = number of node to which source is applied

$\dot{Q}$(I) = heat source value

Conductive Constant Block

KODE, N, DIS1 (N), DIS2 (N) (2I5, 2F15.5)

.

.

.

1110

KODE = 0 or blank

N = Conductor number constant is associated with

DIS1 (N) = Constant $\frac{A}{\Delta X}$ for conductor N associated with node NCOND (1, N)

DIS2 (N) = Constant $\frac{A}{\Delta X}$ for conductor N associated with node NCOND (2, N)

Figure 3-2. Detailed Input Description (Sheet 4 of 6)

Table Block

KODE, L1, L2, LFLAG, Title	(4I5, A60)
X(1), X(2), X(3), X(4), X(5), X(6), X(7)	(7E10.0)
X(8), ... X(L1)	(7E10.0)
Y1 (1), Y1 (2), Y1 (3), . . . , Y1(7)	(7E10.0)
Y1(8) . . . , Y1 (L1)	(7E10.0)
Y2(1), Y2(2), Y2(3), . . . , Y2(7)	(7E10 0)
Y2(8), . . . , Y2(L1)	(7E10.0)
.	
.	
.	
YL2(1), ... ,YL2(L1)	(7E10.0)

Repeat above cards for each table with no blank or additional records between tables. Tables are numbered consecutively starting with 1 by the program.

11100 (at end of table block only) (I5)

KODE = 0, or blank

L1 = number of values of independent variable

L2 = number of dependent variables

LFLAG = index indicating type of table and node number associated with table

= 1	DTIME vs. TIME
>10000: <20000	Boundary Temperature vs. Time for node # = LFLAG - 10000
> 20000 < 30000	Heat Sources vs. Time for node # = LFLAG - 20000
> 30000 < 40000	Conductance vs. Temperature for node # = LFLAG - 30000
> 40000 < 50000	Conductance vs. Time for node # = LFLAG - 40000
> 50000 < 50000	Capacitance vs. Temperature for node # = LFLAG - 50000
= 99999	Variable Properties C_p(T) 1st Table K (T) 2nd Table

Node Number vs. Table Number Block

KODE, (J1(I), J2(I), I = 1, 7)	I5, 7(2I5)
.	
.	
.	
11100	

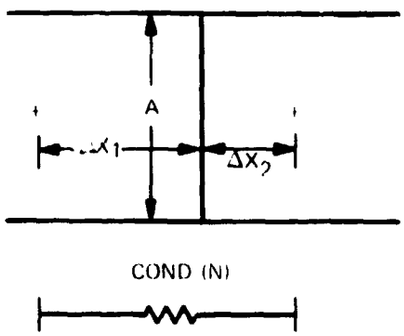
Figure 3-2. Detailed Input Description (Sheet 5 of 6)

KODE		0, or blank
J1(I)		Node number
J2(I)		Table number associated with node number J1(I)
IF J1(1)	=	0 indicates all nodes are associated with J2(1) (table number)

Termination Card

KODE = 11100 Job is terminated

Figure 3-2. Detailed Input Description (Sheet 6 of 6)



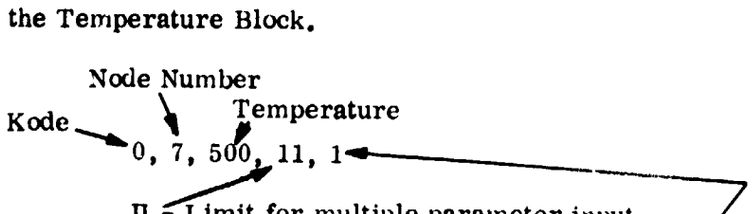
COND (N)

$$\text{COND (N)} = \frac{\frac{K_1 A}{\Delta X_1} \times \frac{K_2 A}{\Delta X_2}}{\frac{K_1 A}{\Delta X_1} + \frac{K_2 A}{\Delta X_2}} = \frac{K_1 \text{ DIS1(N)} \times K_2 \text{ DIS2(N)}}{K_1 \text{ DIS1(N)} + K_2 \text{ DIS2(N)}}$$

Figure 3-3. Parameter A/ ΔX

Multiple Parame[illegible]ption

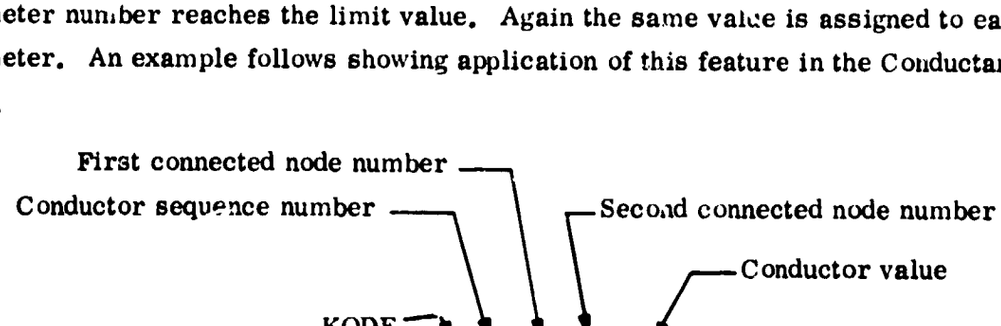
This option permits specification of the same value for a series of parameters, with a single data line. For temperatures or capacitances the node number is incremented by the spacing (JJ) until the limit (II) is reached. Each node specified is assigned the same temperature or capacitance. An example follows showing an application of this feature in the Temperature Block.



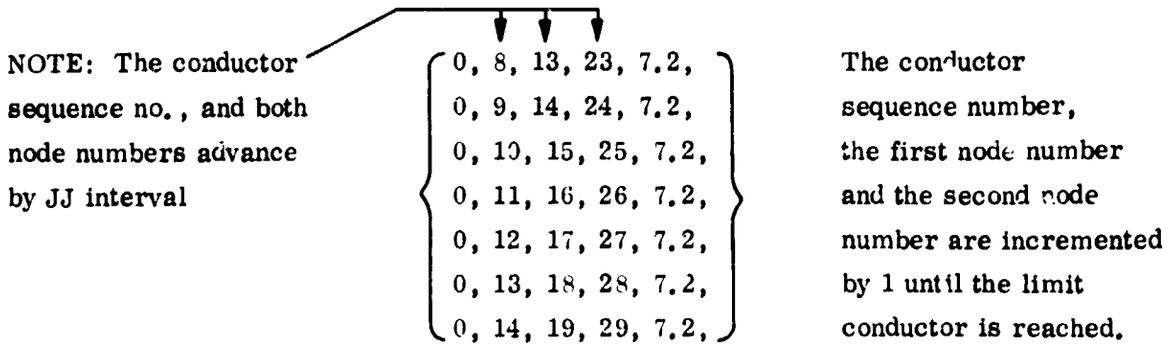
Equivalent to:

0, 7, 500, 0, 8, 500, 0, 9, 500, 0, 10, 500, 0, 11, 500,	The node number in this case is increased by one to the limit 11, spaced by one.

For conductances or radiation couplings the feature is similar except that the parameter number (N) and the two node numbers (I and J) are incremented by the spacing until the parameter number reaches the limit value. Again the same value is assigned to each parameter. An example follows showing application of this feature in the Conductance Block.



This single card using Multiple Parameter Input is equivalent to the following seven cards.



If the value of JJ (spacing) was 2, the equivalent would be:

0, 8, 13, 23, 7.2,
0, 10, 15, 25, 7.2,
0, 12, 17, 27, 7.2,
0, 14, 19, 29, 7.2,

Section 4

SAMPLE PROBLEM NO. 1

The first sample problem provided by the Technical Monitor was a Lockalloy structure with a one inch diameter perturbance. The structure is depicted in Figure 4-1. As shown, it is horseshoe shaped and symmetric about axis A. The model for this structure is comprised of a number of rectangular and circular segmented nodes. It is three layers deep except for the perturbance. The node numbering scheme was provided by the Technical Monitor. Figure 4-2 shows the external boundary conditions and material properties. Note that the heat transfer coefficients vary near the rod. A math model was created representing the structure and is highlighted in Figure 4-3. The model contains 181 iterated nodes, 2 boundary nodes, 181 capacitances, 488 conductors, 60 radiators, 488 conductor constants, a table of physical properties versus temperature and a node/table correspondence block. The first data card is used to set the core allocation for the program; the values just mentioned and the requested 18 eigenvalues for this solution are shown on this card. This input data file was created and executed on the Grumman Cyber 173 computer. The solution is displayed in Figure 4-4. Note the output option taken in this problem was the briefest one (i.e., no heat fluxes, steady-state temperatures or eigenvalues). The initial conditions and the temperatures of each node at each time step were written out. This same problem was run using the Grumman Thermal Analyzer, which employs a forward difference technique. A comparison plot is presented in Figure 4-5. The solid symbols represent the CAVE results while the open symbols represent the thermal analyzer results. The comparison between the two techniques is excellent.

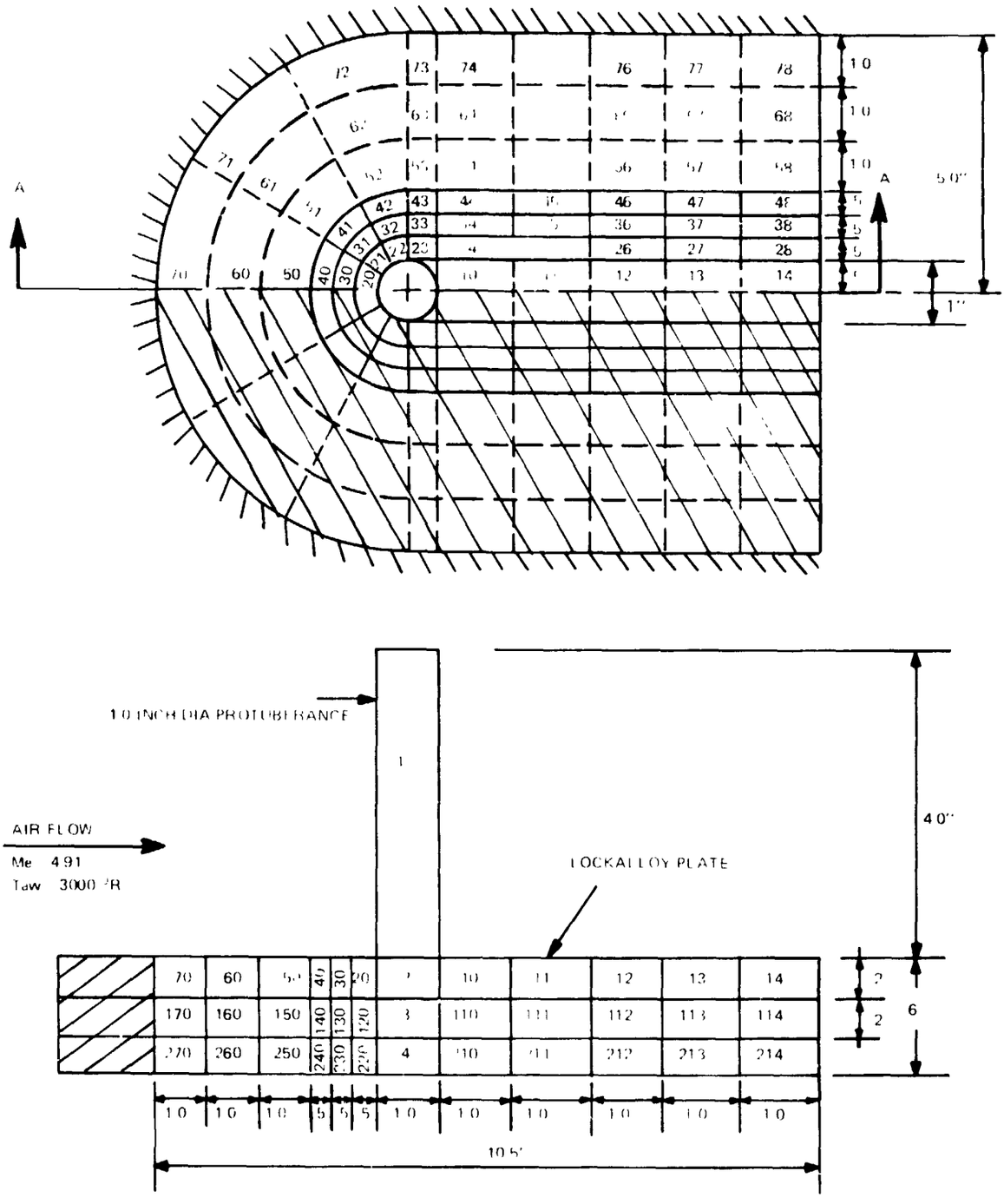


Figure 4-1. Sample Problem No. 1 Geometry Configuration

Taw = 3000 ^{o}R

Tinitial = 960°R (time = 0)

Start time = 0

Final time = 40 sec

Lockalloy Emissivity = 0.8

View Factor = 1.0

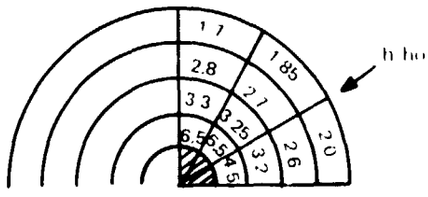
Background Temperature = 519°R

Convection Nodes Surface: 10 to 14, 23 to 28, 33 to 38
43 to 48, 53 to 58, 60 to 68
and 70 to 78 have

h/ho = 1.0

where h_o = 24.5 BTU/hr ft^2 ^{o}R

The interference heating to the remaining surface nodes is listed below: (See NASA TND-1372)



NODE	h/ho
20	6.5
21	5.5
22	4.5
30	3.3
31	3.25
32	3.2
40	2.8
41	2.7
42	2.6
50	1.7
51	1.85
52	2.00

Physical Properties

	540°R	860°R	1060°R	1260°R
ρ(lbm/in^3)	.0756	.0756	.0756	.0756
Cp (Btu/lbm ^{o}R)	.395	.511	.548	.562
K BTU/(HR FT^2 ^{o}R/FT)	123.0	99.5	89.0	81.5

Figure 4-2. Sample Problem No. 1 Boundary Conditions and Properties

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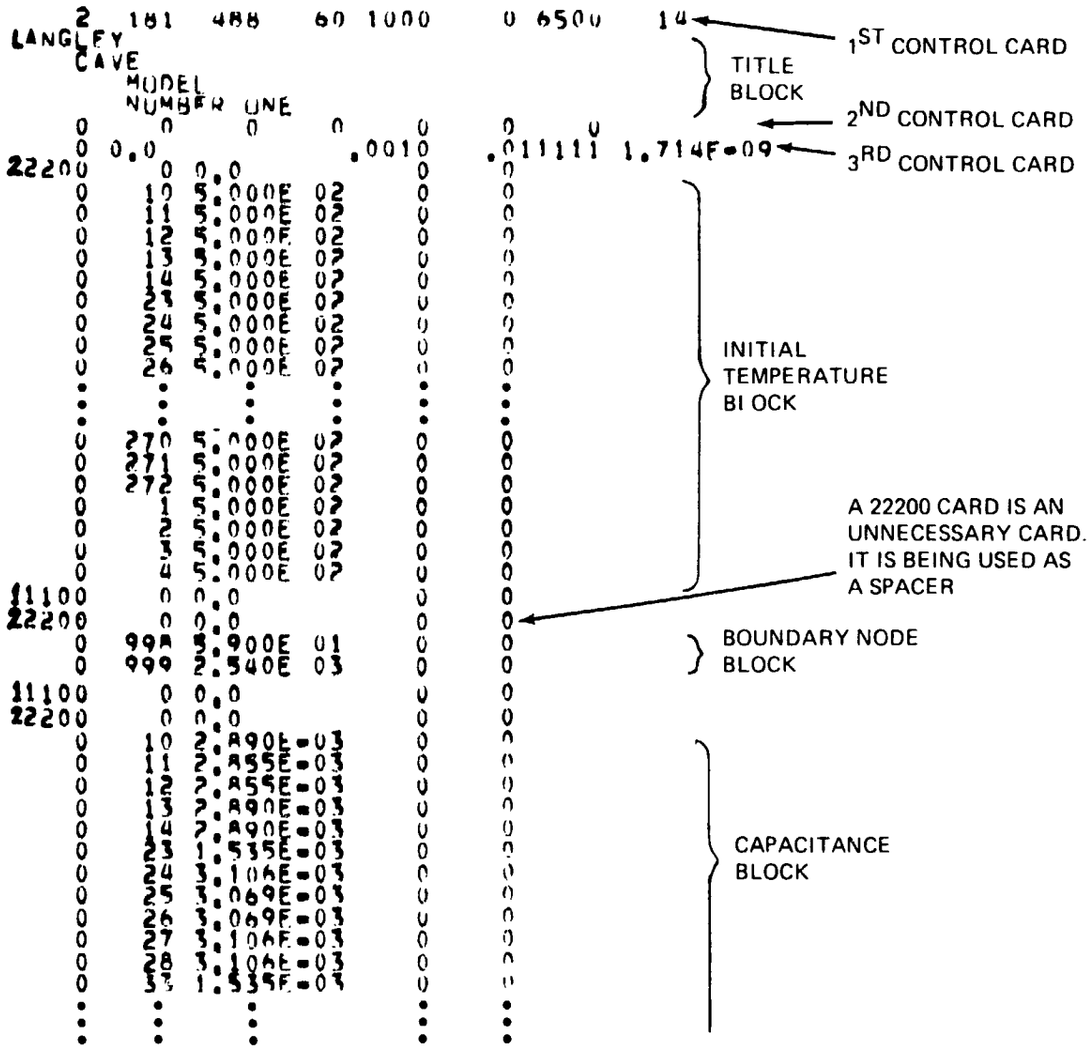


Figure 4-3. Input File for Sample Problem No. 1 (Sheet 1 of 3)

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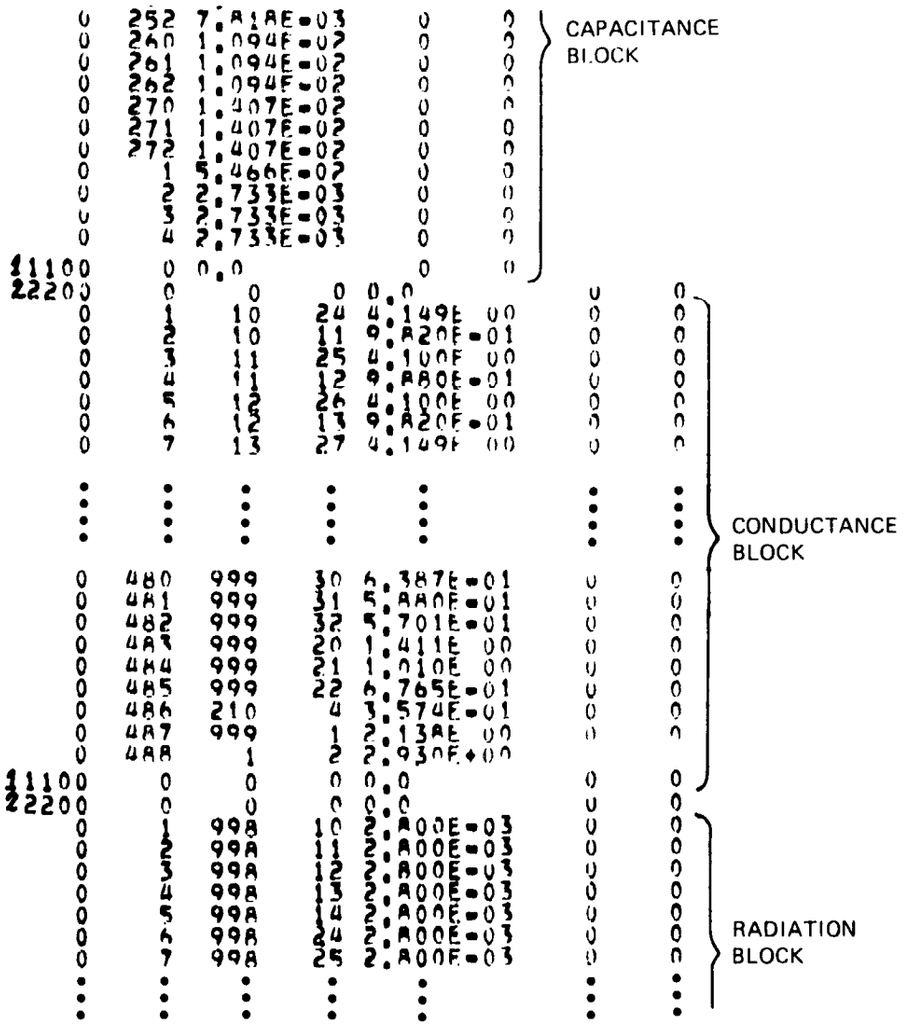


Figure 4-3. Input File for Sample Problem No. 1 (Sheet 2 of 3)

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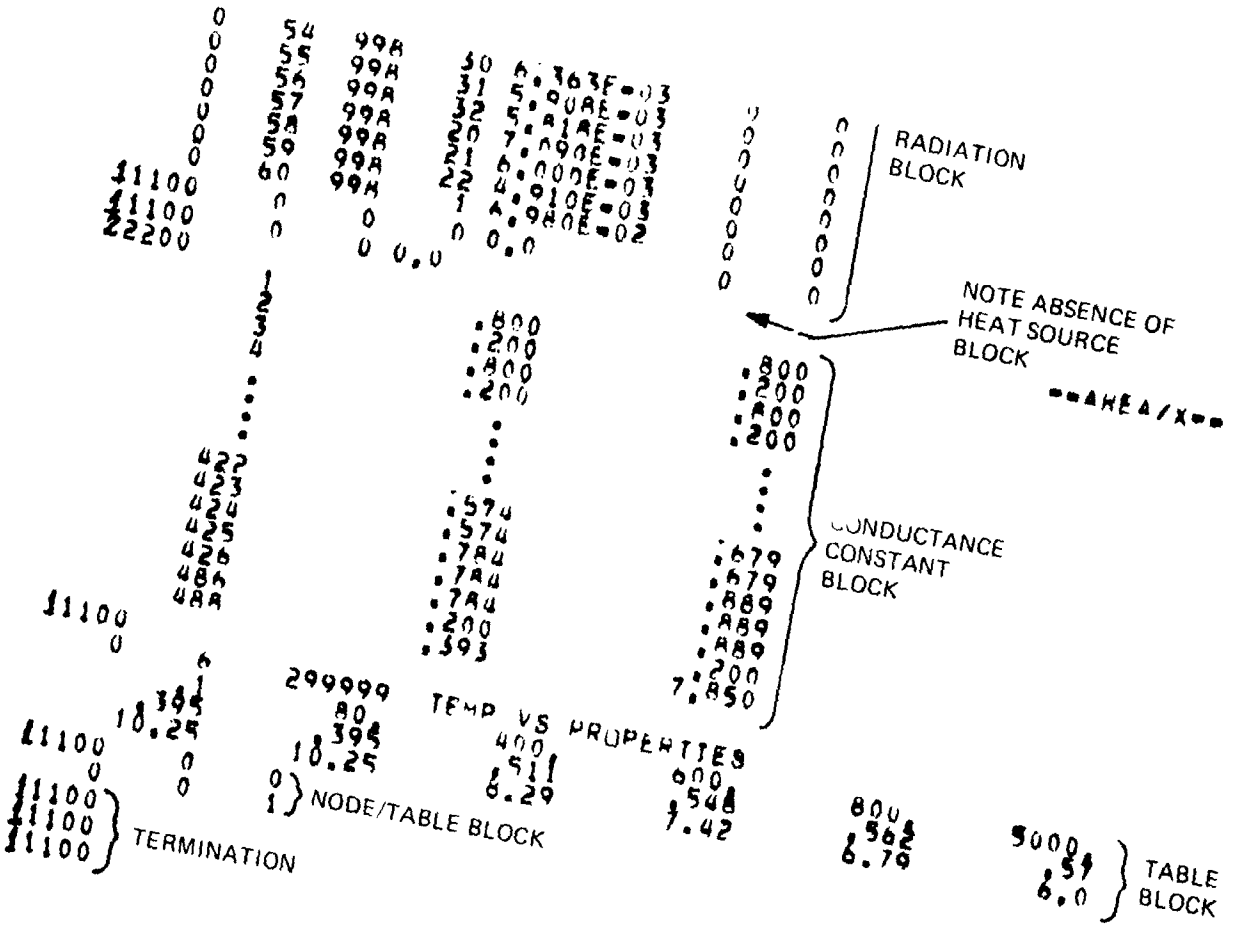


Figure 4-3. Input File for Sample Problem No. 1 (Sheet 3 of 3)

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```
$STORE
NUMBND  = 9,
NUMITR  = 181,
NUMCON  = 488,
NUMTCN  = 1096,
NUMNOD  = 1000,
NUMFLX  = 0,
NSTR    = 6500,
NEVALU  = 10,
NUMTOT  = 183,
NUMSCR  = 1525,
NUMRAD  = 60,
SEND
THIS RUN REQUIRES A DATA AREA OF      18148 WORDS
         1         362         183         183         488         976         183         120        1000           0
         0         183         183          60        2192         181          10        1810        1523        6500
       183         181         183         488         488         488
         1         363         546         729        1217        2193        2376        2496        3496        3496
      3496        3679        3862        5925        6114        6295        6305        8115        9638       16138
     16321       16502       16684       17173       17661
HIGHEST MEMORY IN HEXADECIMAL IS  00011894
   183   181    10   488    60  1000     0  1523  6500
```

Figure 4-4. Output for Sample Problem No. 1 (Sheet 1 of 14)

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```
LANGLEY
    CAVE
        MODEL
        NUMBER ONE
NUMBER OF ITERATED NODES     =    181
NUMBER OF BOUNDARY NODES     =      2
NUMBER OF CONDUCTION LINKS   =    484
NUMBER OF RADIATION LINKS    =     60
NUMBER OF HEAT SOURCES       =      0

TIME = 0.                    DTIME =  .10000000E-02      FTIME =  .11111000E-01

INITIAL TEMPERATURES OF ITERATED NODES
   T( 10) =  .5000000E+03   T( 11) =  .5000000E+03   T( 12) =  .5000000E+03   T( 13) =  .5000000E+03   T( 14) =  .5000000E+03
   T( 23) =  .5000000E+03   T( 24) =  .5000000E+03   T( 25) =  .5000000E+03   T( 26) =  .5000000E+03   T( 27) =  .5000000E+03
   T( 28) =  .5000000E+03   T( 33) =  .5000000E+03   T( 34) =  .5000000E+03   T( 35) =  .5000000E+03   T( 36) =  .5000000E+03
   T( 37) =  .5000000E+03   T( 38) =  .5000000E+03   T( 43) =  .5000000E+03   T( 44) =  .5000000E+03   T( 45) =  .5000000E+03
   T( 46) =  .5000000E+03   T( 47) =  .5000000E+03   T( 48) =  .5000000E+03   T( 53) =  .5000000E+03   T( 54) =  .5000000E+03
   T( 55) =  .5000000E+03   T( 56) =  .5000000E+03   T( 57) =  .5000000E+03   T( 58) =  .5000000E+03   T( 63) =  .5000000E+03
   T( 64) =  .5000000E+03   T( 65) =  .5000000E+03   T( 66) =  .5000000E+03   T( 67) =  .5000000E+03   T( 68) =  .5000000E+03
   T( 73) =  .5000000E+03   T( 74) =  .5000000E+03   T( 75) =  .5000000E+03   T( 76) =  .5000000E+03   T( 77) =  .5000000E+03
   T( 78) =  .5000000E+03   T( 11) =  .5000000E+03   T(111) =  .5000000E+03   T(112) =  .5000000E+03   T(113) =  .5000000E+03
   T(114) =  .5000000E+03   T(123) =  .5000000E+03   T(124) =  .5000000E+03   T(125) =  .5000000E+03   T(126) =  .5000000E+03
   T(127) =  .5000000E+03   T(128) =  .5000000E+03   T(133) =  .5000000E+03   T(134) =  .5000000E+03   T(135) =  .5000000E+03
   T(136) =  .5000000E+03   T(137) =  .5000000E+03   T(138) =  .5000000E+03   T(143) =  .5000000E+03   T(144) =  .5000000E+03
   T(145) =  .5000000E+03   T(146) =  .5000000E+03   T(147) =  .5000000E+03   T(148) =  .5000000E+03   T(153) =  .5000000E+03
   T(154) =  .5000000E+03   T(155) =  .5000000E+03   T(156) =  .5000000E+03   T(157) =  .5000000E+03   T(158) =  .5000000E+03
   T(163) =  .5000000E+03   T(164) =  .5000000E+03   T(165) =  .5000000E+03   T(166) =  .5000000E+03   T(167) =  .5000000E+03
   T(168) =  .5000000E+03   T(173) =  .5000000E+03   T(174) =  .5000000E+03   T(175) =  .5000000E+03   T(176) =  .5000000E+03
   T(177) =  .5000000E+03   T(178) =  .5000000E+03   T(210) =  .5000000E+03   T(211) =  .5000000E+03   T(212) =  .5000000E+03
   T(213) =  .5000000E+03   T(214) =  .5000000E+03   T(223) =  .5000000E+03   T(224) =  .5000000E+03   T(225) =  .5000000E+03
   T(226) =  .5000000E+03   T(227) =  .5000000E+03   T(228) =  .5000000E+03   T(233) =  .5000000E+03   T(234) =  .5000000E+03
   T(235) =  .5000000E+03   T(236) =  .5000000E+03   T(237) =  .5000000E+03   T(238) =  .5000000E+03   T(243) =  .5000000E+03
   T(244) =  .5000000E+03   T(245) =  .5000000E+03   T(246) =  .5000000E+03   T(247) =  .5000000E+03   T(248) =  .5000000E+03
   T(253) =  .5000000E+03   T(254) =  .5000000E+03   T(255) =  .5000000E+03   T(256) =  .5000000E+03   T(257) =  .5000000E+03
   T(258) =  .5000000E+03   T(263) =  .5000000E+03   T(264) =  .5000000E+03   T(265) =  .5000000E+03   T(266) =  .5000000E+03
   T(267) =  .5000000E+03   T(268) =  .5000000E+03   T(273) =  .5000000E+03   T(274) =  .5000000E+03   T(275) =  .5000000E+03
   T(276) =  .5000000E+03   T(277) =  .5000000E+03   T(278) =  .5000000E+03   T( 20) =  .5000000E+03   T( 21) =  .5000000E+03
   T( 22) =  .5000000E+03   T( 30) =  .5000000E+03   T( 31) =  .5000000E+03   T( 32) =  .5000000E+03   T( 40) =  .5000000E+03
   T( 41) =  .5000000E+03   T( 42) =  .5000000E+03   T( 50) =  .5000000E+03   T( 51) =  .5000000E+03   T( 52) =  .5000000E+03
   T( 60) =  .5000000E+03   T( 61) =  .5000000E+03   T( 70) =  .5000000E+03   T( 71) =  .5000000E+03   T( 72) =  .5000000E+03
   T( 79) =  .5000000E+03   T(120) =  .5000000E+03   T(121) =  .5000000E+03   T(122) =  .5000000E+03   T(130) =  .5000000E+03
   T(131) =  .5000000E+03   T(132) =  .5000000E+03   T(140) =  .5000000E+03   T(141) =  .5000000E+03   T(142) =  .5000000E+03
   T(150) =  .5000000E+03   T(151) =  .5000000E+03   T(152) =  .5000000E+03   T(160) =  .5000000E+03   T(161) =  .5000000E+03
   T(169) =  .5000000E+03   T(170) =  .5000000E+03   T(171) =  .5000000E+03   T(172) =  .5000000E+03   T(220) =  .5000000E+03
   T(221) =  .5000000E+03   T(222) =  .5000000E+03   T(230) =  .5000000E+03   T(231) =  .5000000E+03   T(232) =  .5000000E+03
   T(240) =  .5000000E+03   T(241) =  .5000000E+03   T(242) =  .5000000E+03   T(250) =  .5000000E+03   T(251) =  .5000000E+03
   T(252) =  .5000000E+03   T(260) =  .5000000E+03   T(261) =  .5000000E+03   T(262) =  .5000000E+03   T(270) =  .5000000E+03
   T(271) =  .5000000E+03   T(272) =  .5000000E+03   T(  1) =  .5000000E+03   T(  2) =  .5000000E+03   T(  3) =  .5000000E+03
   T(  4) =  .5000000E+03   T(

INITIAL TEMPERATURES OF BOUNDARY NODES
   T(998) =  .5000000E+02   T(999) =  .2540000E+04   T(

INITIAL THERMAL CAPACITANCES OF ITERATED NODES
CAP( 10) =  .2890000E-02   CAP( 11) =  .2855000E-02   CAP( 12) =  .2855000E-02   CAP( 13) =  .2890000E-02
CAP( 14) =  .2890000E-02   CAP( 23) =  .1535000E-02   CAP( 24) =  .3106000E-02   CAP( 25) =  .3106000E-02
CAP( 26) =  .1535000E-02   CAP( 27) =  .3106000E-02   CAP( 28) =  .3106000E-02   CAP( 33) =  .1535000E-02
```

Figure 4-4. Output for Sample Problem No. 1 (Sheet 2 of 14)

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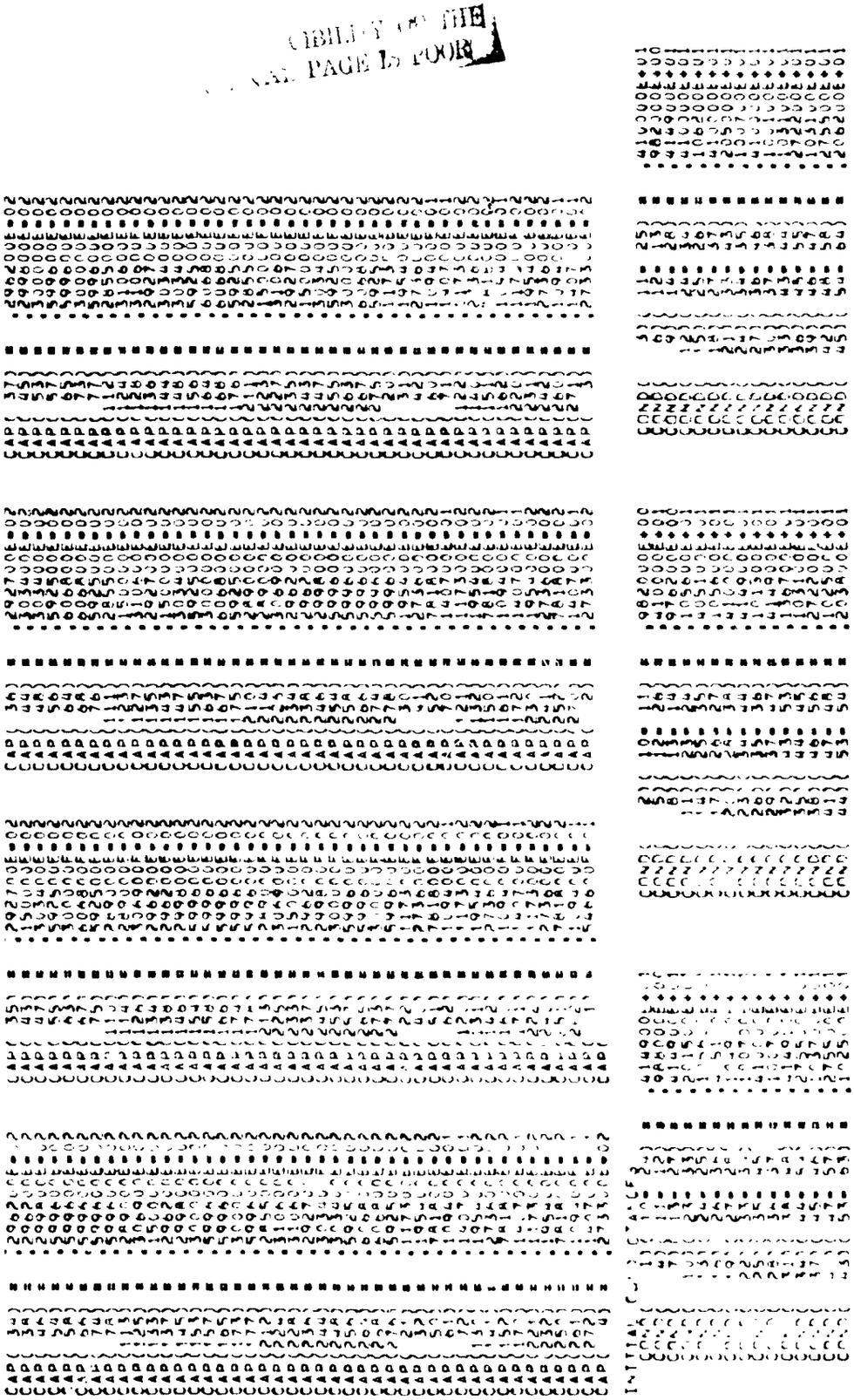


Figure 4-4. Output for Sample Problem No. 1 (Sheet 3 of 14)

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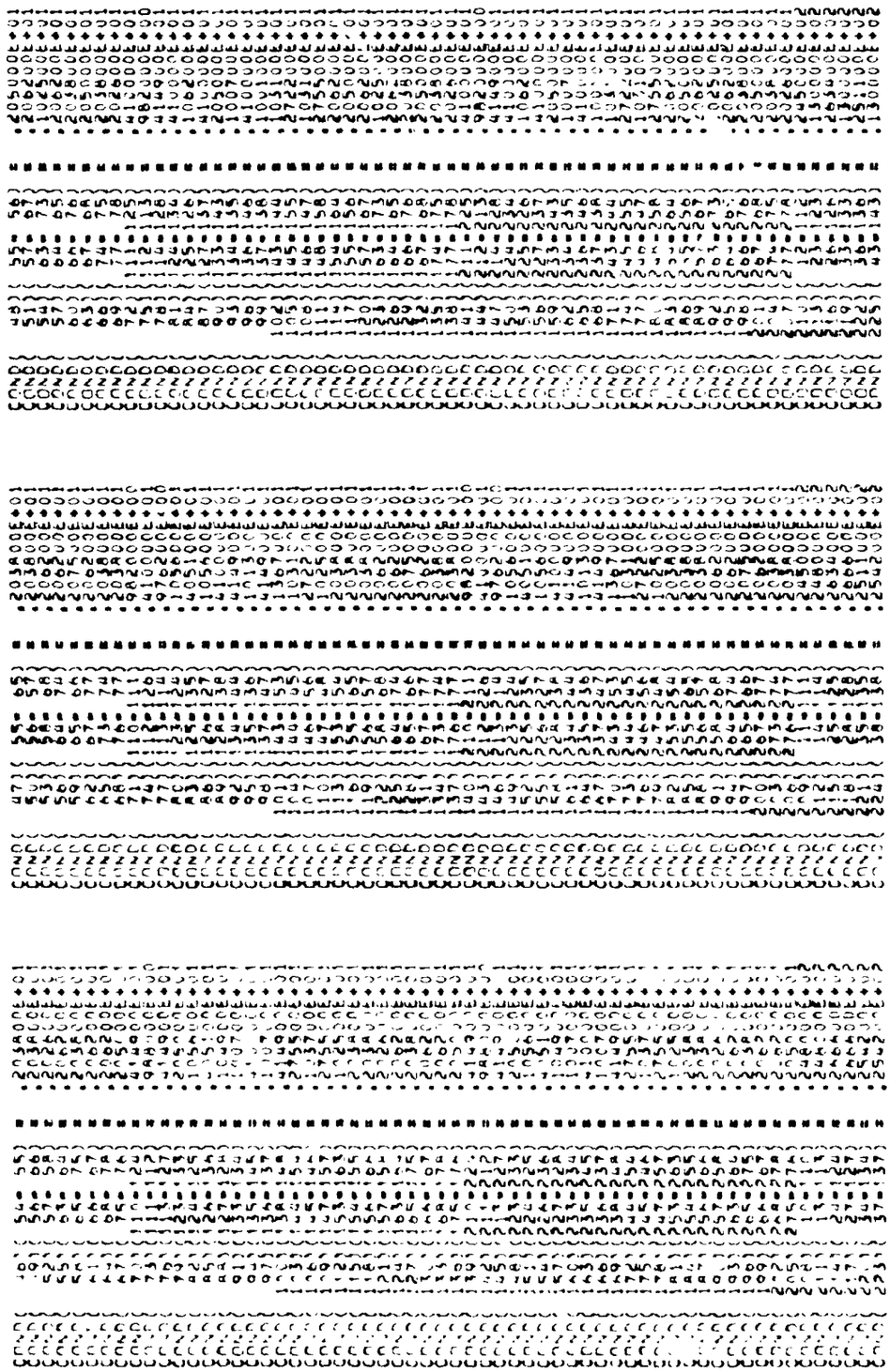


Figure 4-4. Output for Sample Problem No. 1 (Sheet 4 of 14)

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Figure 4-4. Output for Sample Problem No. 1 (Sheet 5 of 14)

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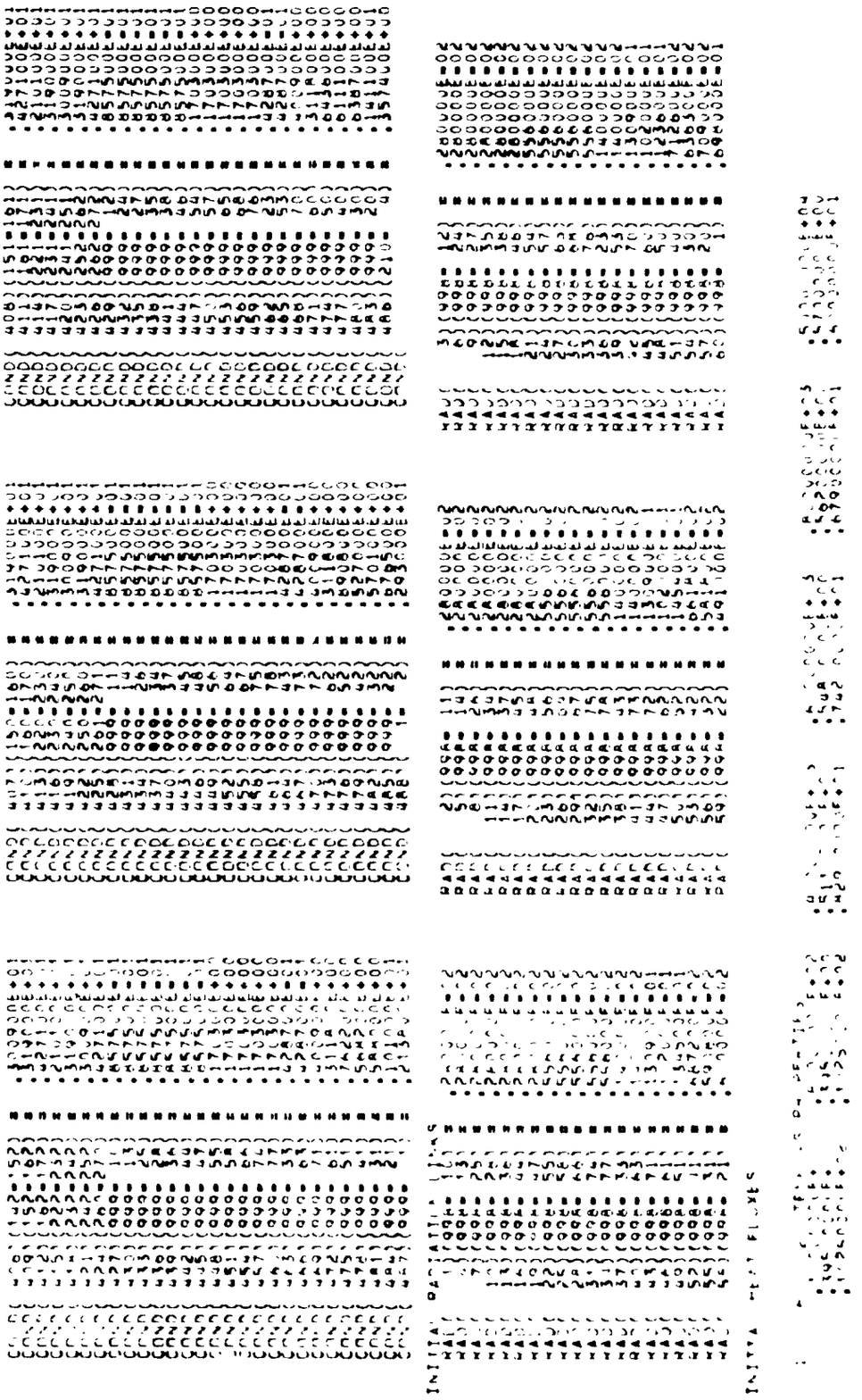


Figure 4-4. Output for Sample Problem No. 1 (Sheet 6 of 14)

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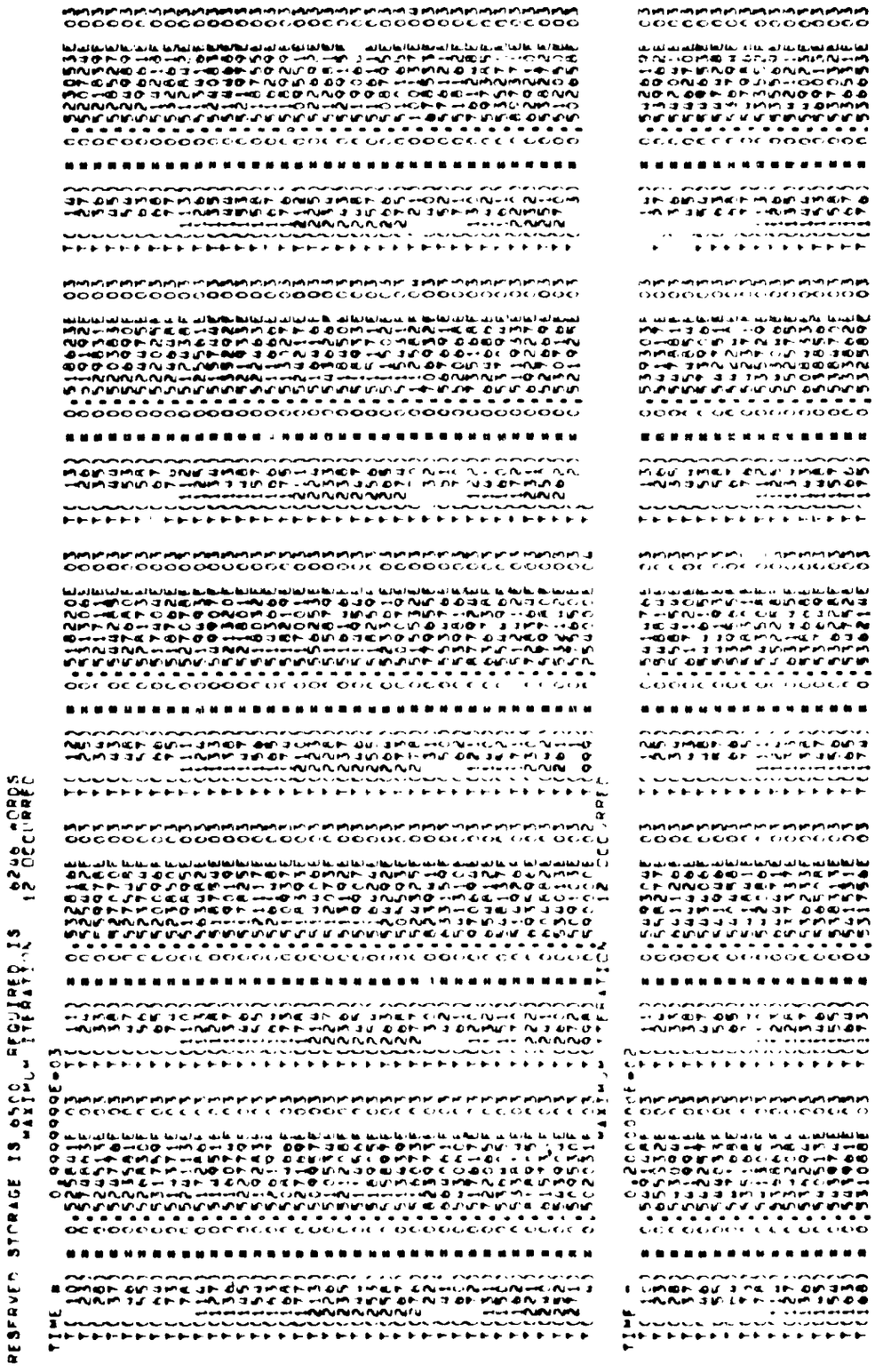


Figure 1-1. Output for Sample Problem No. 1 (Sheet 7 of 14)

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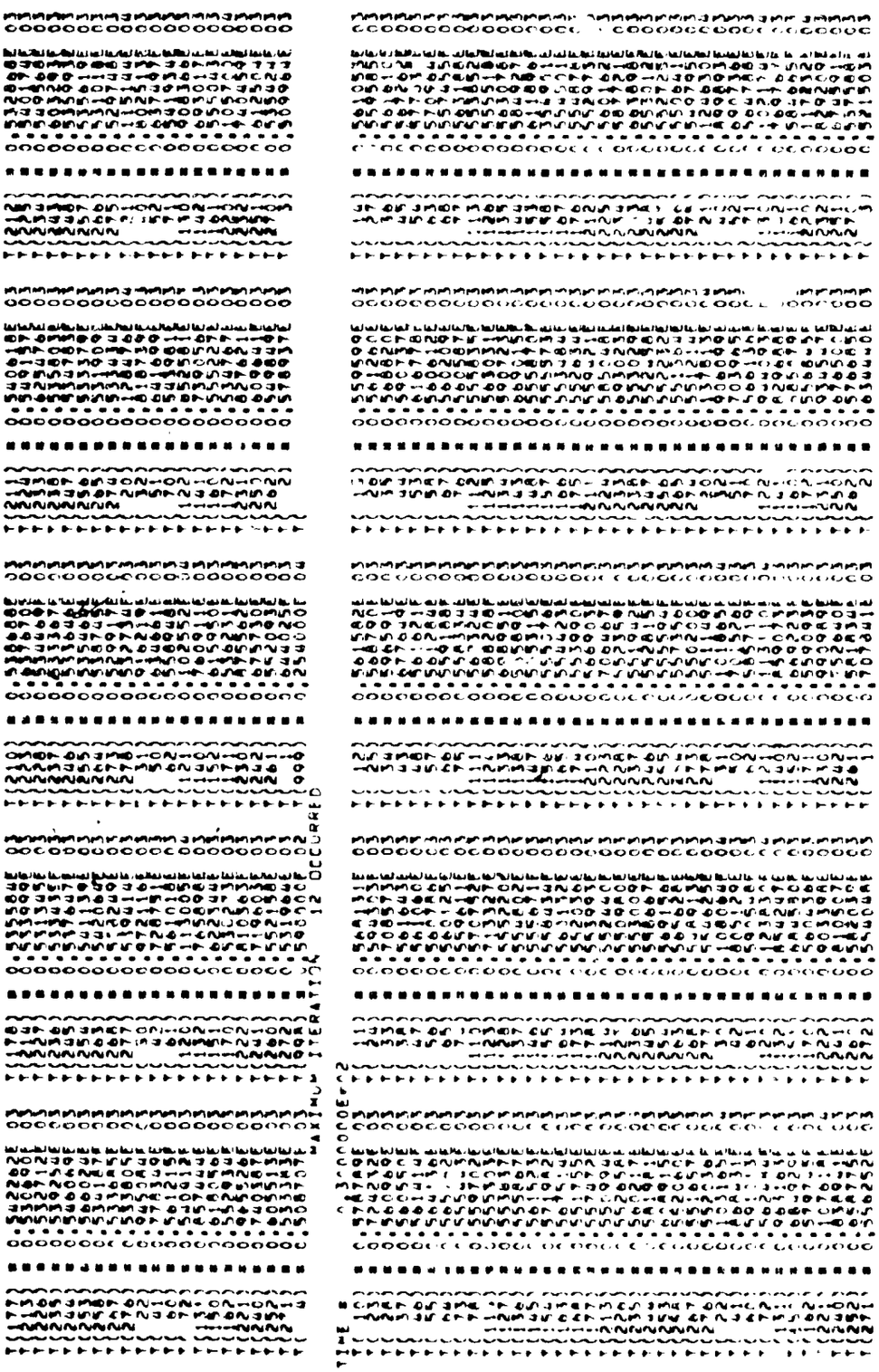


Figure 4-4. Output for Sample Problem No. 1 (Sheet 3 of 14)

REPRODUCIBILITY OF THE
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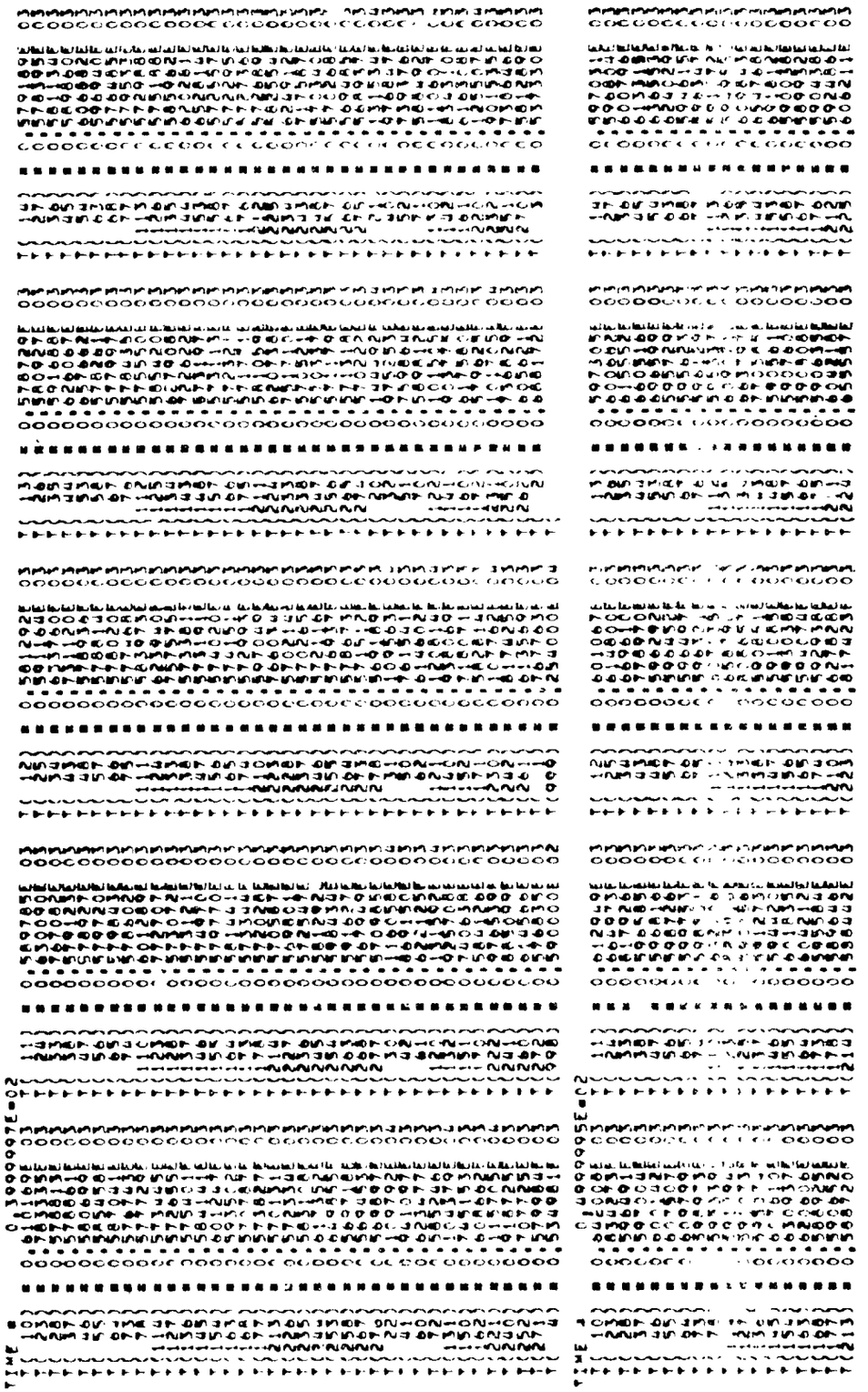


Figure 4-4. Output for Sample Problem No. 1 (Sheet 9 of 14)

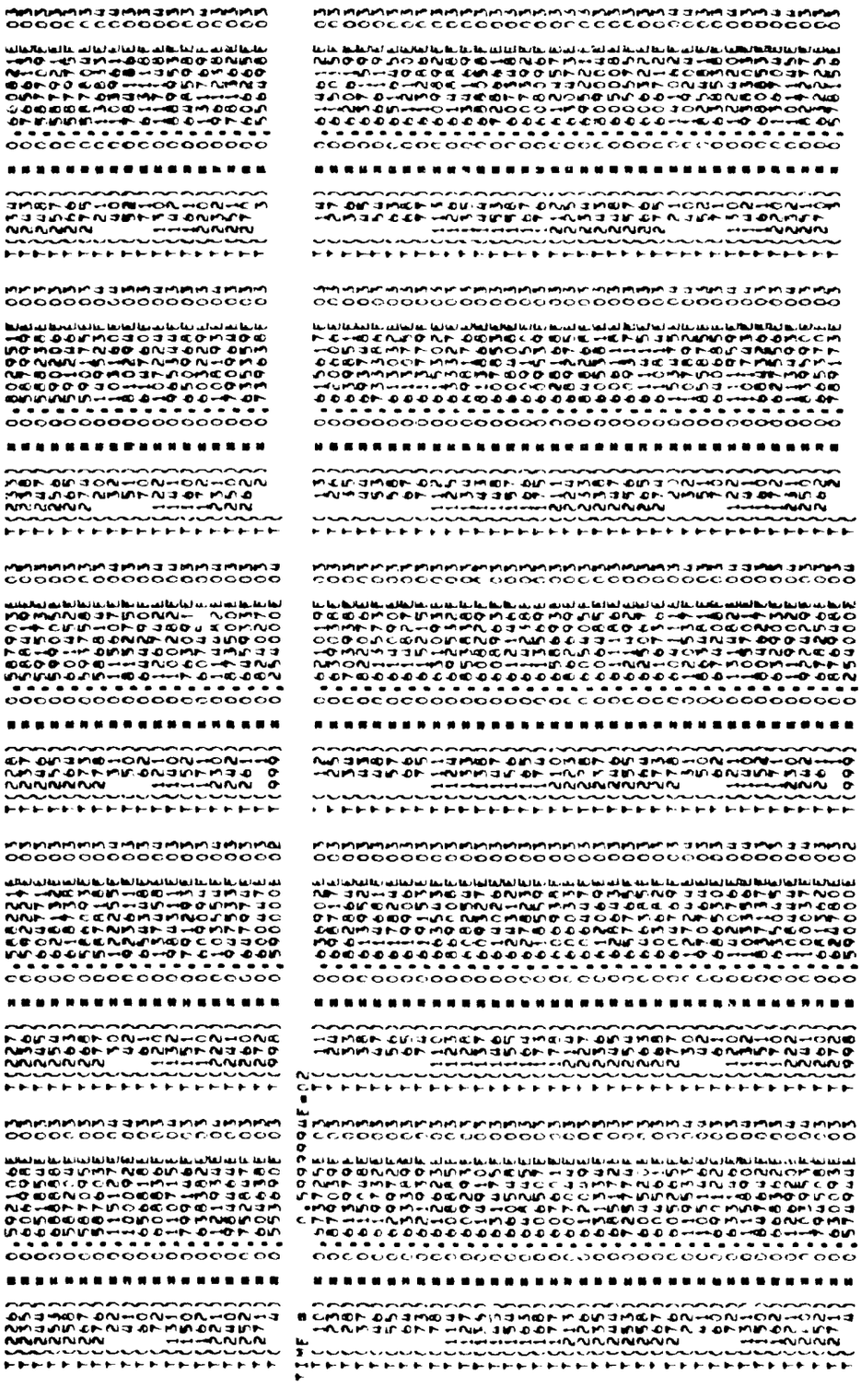


Figure 4-4. Output for Sample Problem No. 1 (Sheet 10 of 14)

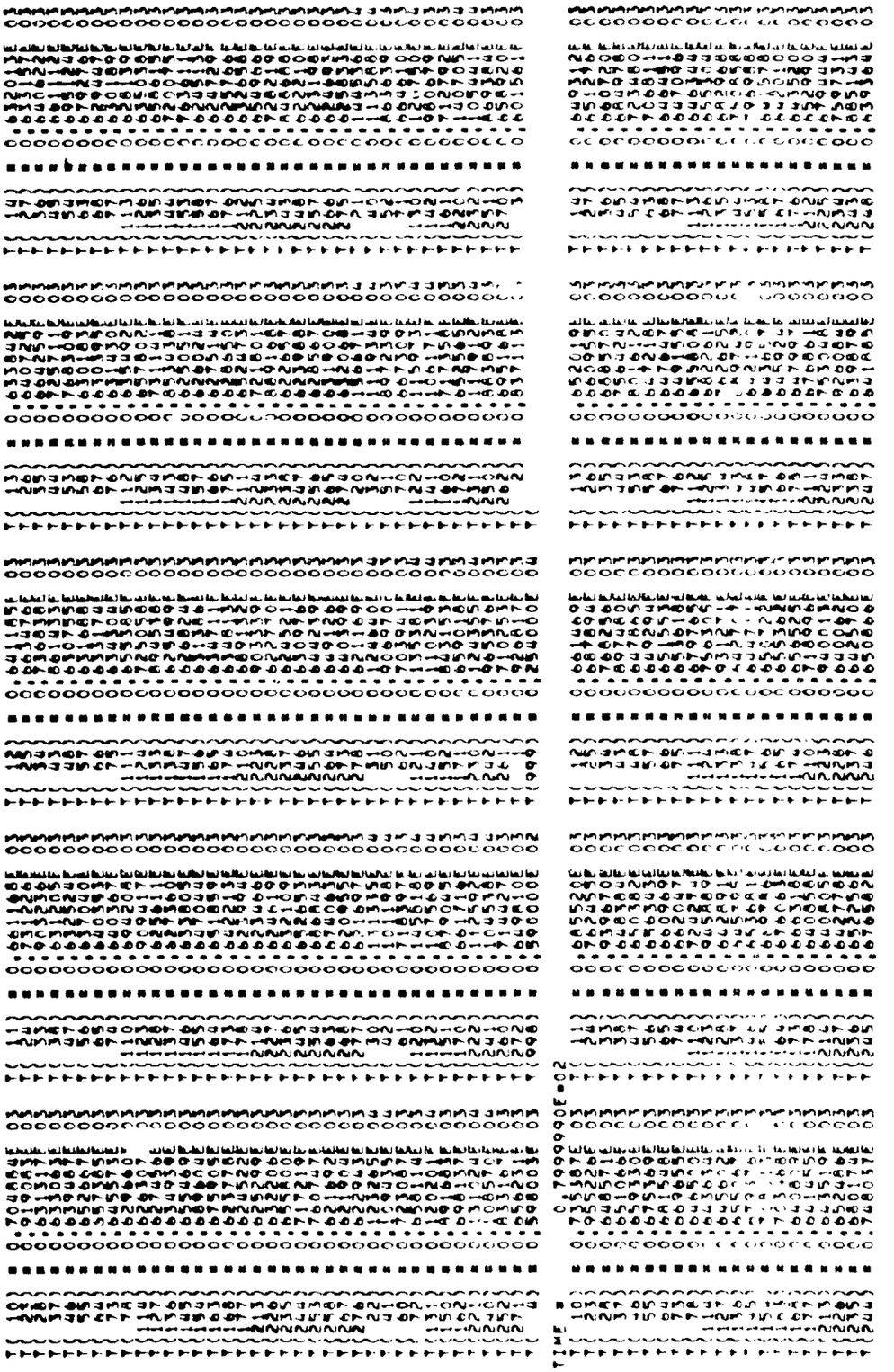


Figure 4-4. Output for Sample Problem No. 1 (Sheet 11 of 14)

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Figure 4-4. Output for Sample Problem No. 1 (Sheet 12 of 14)

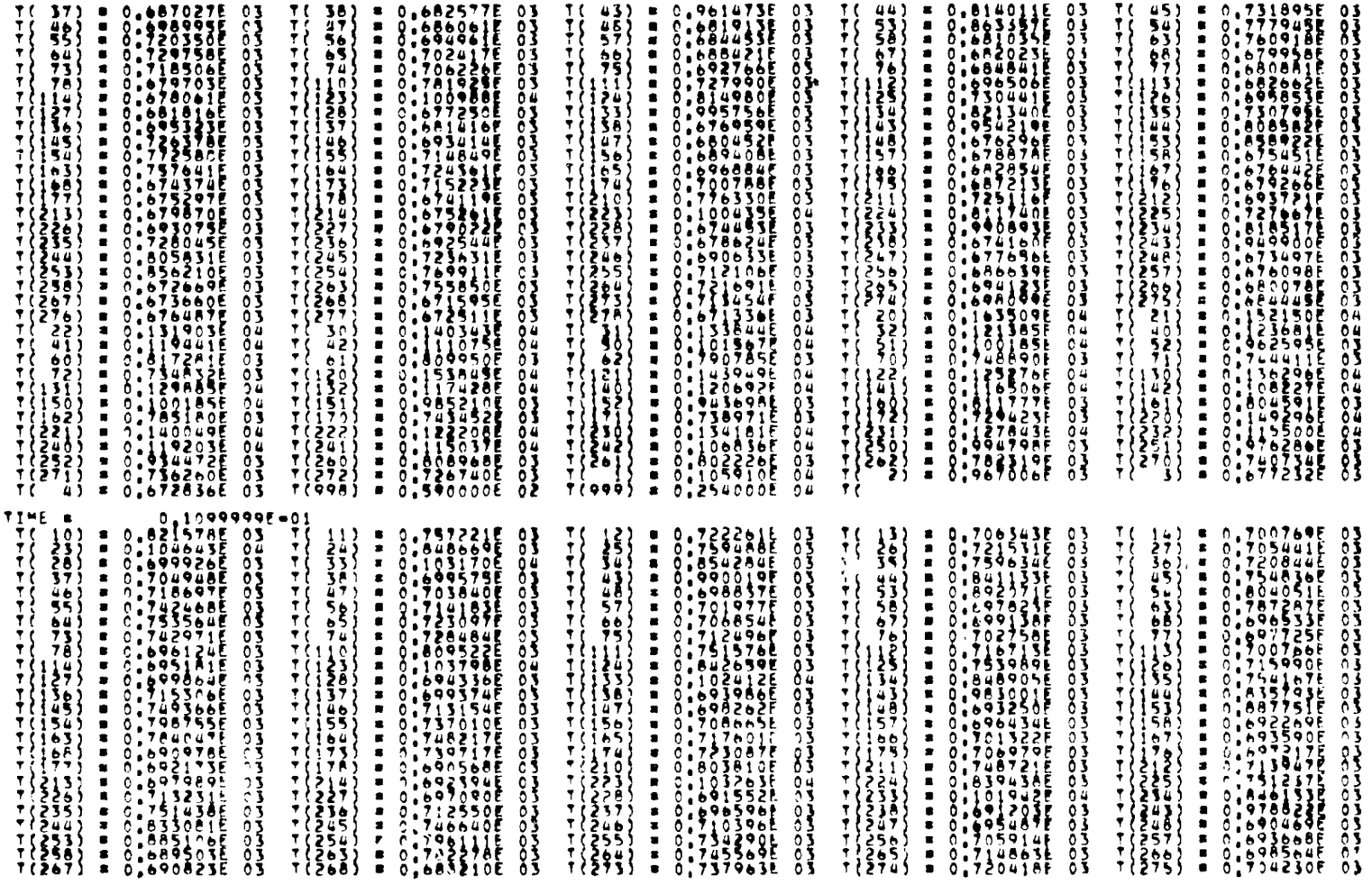


Figure 4-4. Output for Sample Problem No. 1 (Sheet 13 of 14)

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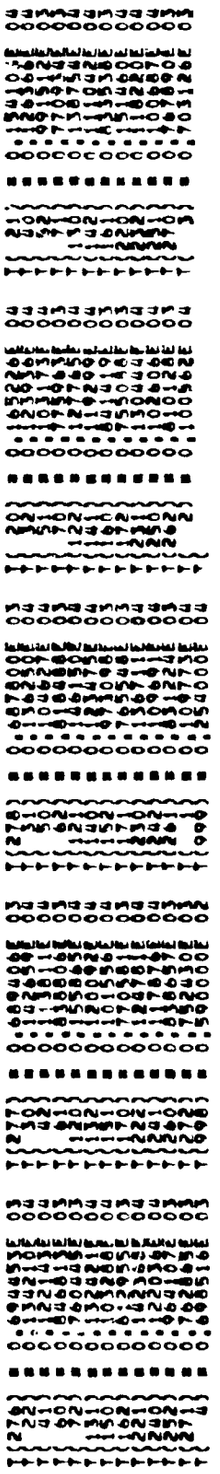


Figure 4-4. Output for Sample Problem No. 1 (Sheet 14 of 14)

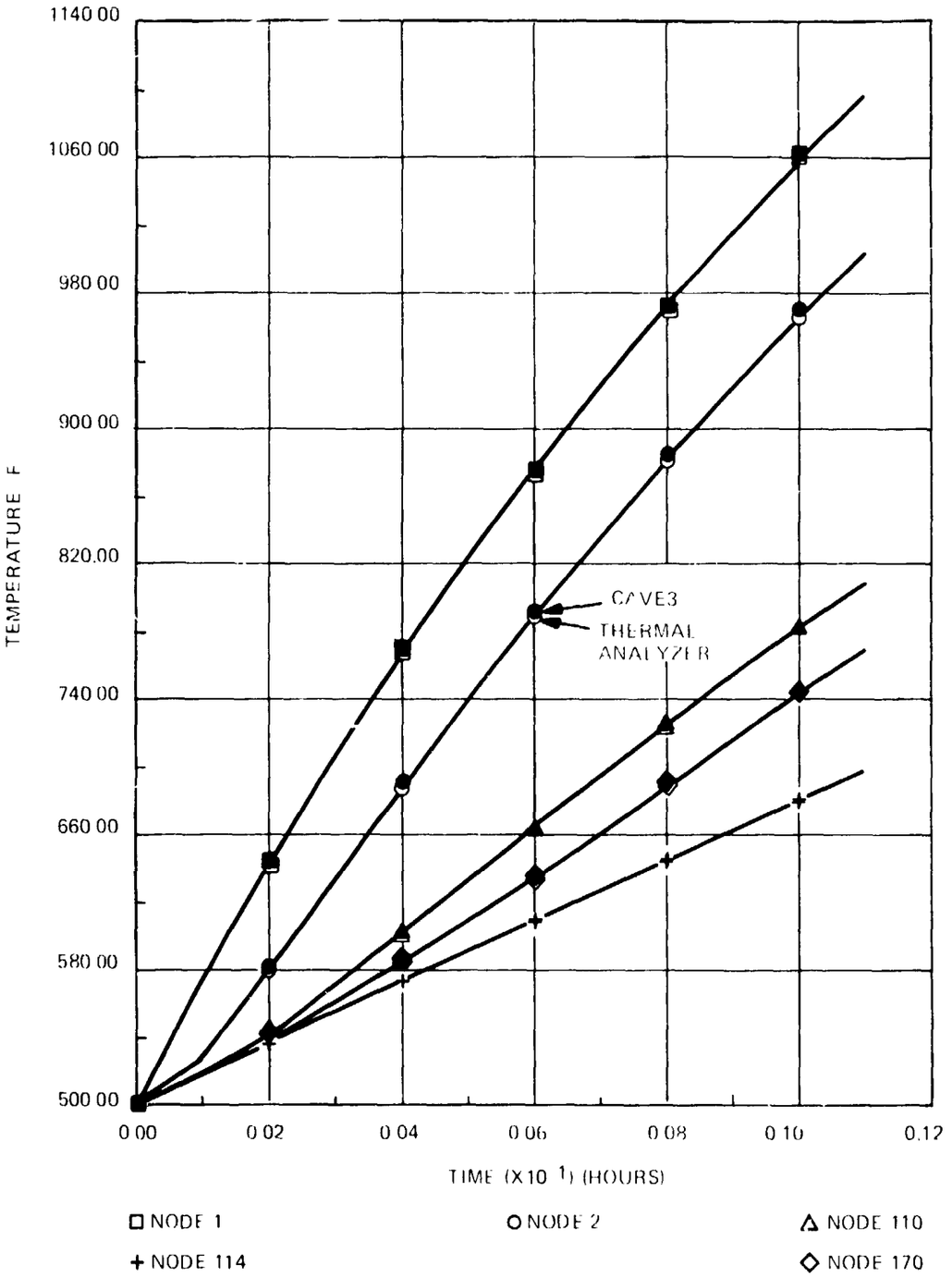


Figure 4-5. CAVE3 Model 1 Verification Plot

Section 5

SAMPLE PROBLEM NO. 2

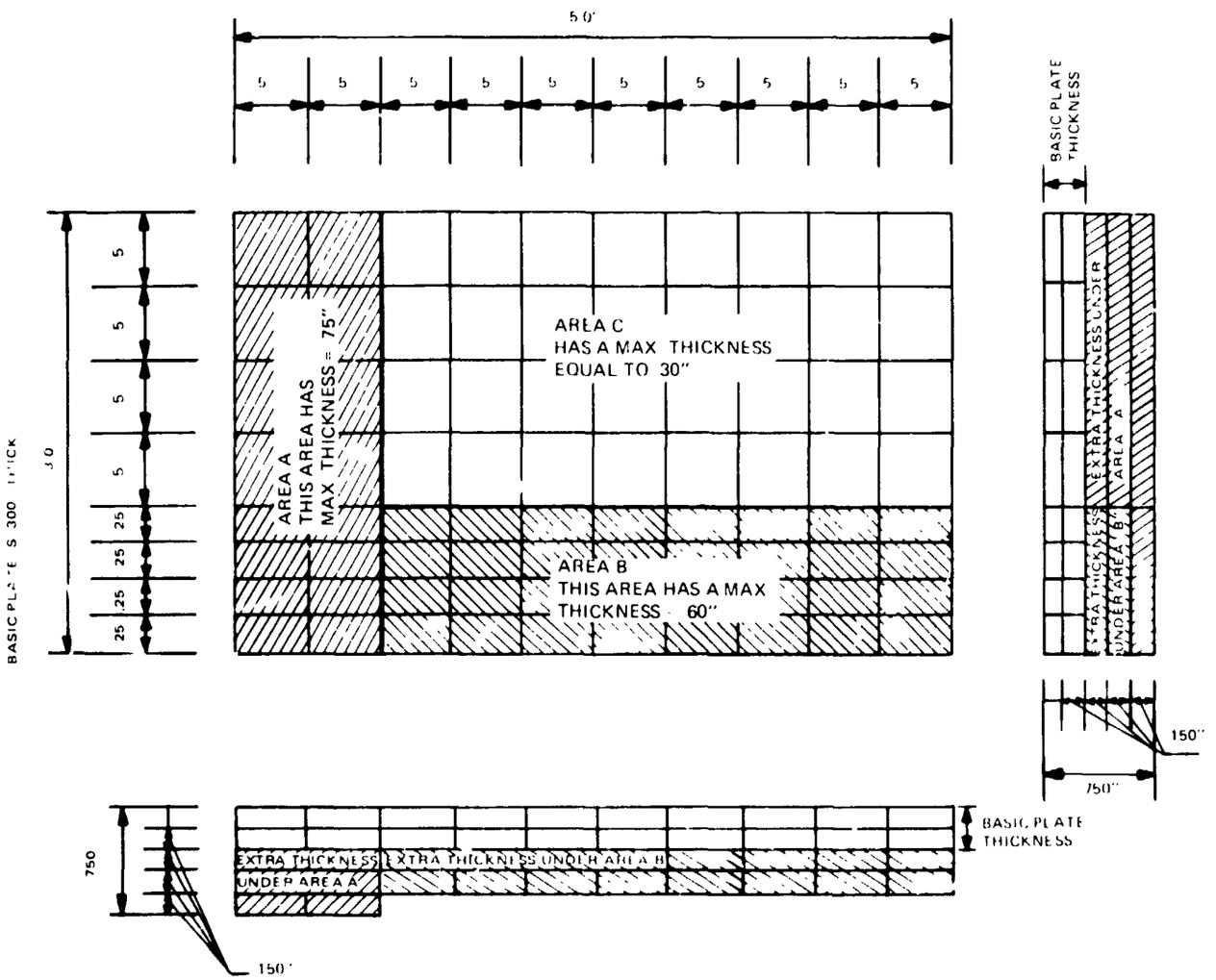
Sample problem No. 2 is displayed in Figures 5-1 to 5-4; it is actually three problems. The first problem, or Model 2A, is a 160 node model (flat plate) exposed to the given top surface boundary conditions shown in Figure 5-1 and 5-3 with all other surfaces being adiabatic. The entire model is made of Lockalloy and its physical properties are displayed in Figure 5-4. The geometry and node breakdown are presented in Figure 5-1. The geometry consists of three distinct regions, A, B, and C. These regions represent areas of buildup for problems Model 2A & B and 2C. Model 2B is constructed by adding an additional Lockalloy layer under regions A and B. This creates a 256 node model, with Model 2A being the basic core. Model 2C is made up of Model 2B and an additional layer of Lockalloy under region A resulting in a 272 node model. Figure 5-2 depicts the nodal arrangement for each of the three models. Note that only the additions are represented, i.e., Model 2B uses the Model 2A numbering plus the layers shown for Model 2B. An input data set has been created for each of the models presented and is displayed in Figures 5, 6 and 7. The data format is essentially identical in each case, so a discussion of the Model 2A data input will be addressed while noting any differences in the remaining model input.

The first control card informs the program that the model consists of two boundary nodes, 160 iterated nodes, 444 conductors, 80 radiators, the highest node number is 1000 (actually 999 in the model), and 0 heat sources. Models 2B and 2C have increased the number of iterated nodes and conductors on this card. An estimate of reserved storage was made at 12500 words. This number is based on the data size and a user "feel" for its estimated size which comes with program use. It should be noted that the output displays the actual reserve storage needed and in this case it was 7269 words. Therefore the input value could have been less. The user also chose to use 14 eigenvalues and employed both the diagnostic option and the flux option. Models 2B and 2C used the default output option which displays only the initial conditions and the temperature time history. The user then input the desired title. Note four lines must be used. The example shows three lines of text and a blank line. On the second control card the user indicates the inputs are to be in degrees Fahrenheit. The third control card indicated an

initial time of zero, a time step of 0.01 and a final time of 0.1. The unit of time in this case is hours which is specified implicitly in the choice of units for thermal conductivity and radiation couplings. The Stephan-Boltzmann constant has also been included as an input which indicates that the values for the radiation couplings do not have this value folded into them. The 22200 is used as a comment card and in this case it is used as a separator. The next block encountered is the initial temperature block and indicates that all 160 nodes are initially at 500°F. The block is terminated by the 11100 card. Note in Figure 5-6 and 5-7 that the initial temperature block has been increased to 256 nodes and 272 nodes for Model 2B and Model 2C respectively. The boundary nodes 998 and 999 are displayed next at 2390°F and 59°F. This data is followed by the capacitance block (mass times specific heat) for each iterated node. Again note the additional capacitances listed for Models 2B and 2C. The conductance links are established next and represent an overall UA computation. Both conduction links (iterated node to iterated node) and convective links (iterated node to boundary node) are represented. The number of conductance links increased dramatically from model to model (444 to 695 to 727) due to the increase in the nodal definition. Note the use of the multiple parameter option in the conductance blocks of Model 2B and Model 2C to minimize the input. The user set-up conductance values for 48 conductors with just 5 lines of input (Figure 5-6). The radiation block follows with the first surface only represented (80 nodes) since it is the only surface exposed to the radiation boundary condition. This block is followed by the conductance constant block and represents the value of $A/\Delta X$ for each iterated conductance link, i.e., all links not exposed to boundary notes. The final 2 blocks deal with table descriptions. The first represents the change in specific heat and conductivity with temperature. Note the units in this case are °F and inches. The node/table correspondence uses this table to describe the property changes and relates table to node number. The final card entered is the termination card.

Figures 5-8 to 5-10 represent the resulting output for each of these three executions. Figure 5-8 is the output from the Model 2A run. It includes the output from the diagnostic and flux options. Figures 5-9 and 5-10 represent the default output which is the initial conditions plus the temperature time history of Model 2B and 2C. Referring to Figure 5-8 after the inital conditions are printed the program displays the steady-state temperature solution followed by the eigenvectors for the number of dominant eigenvalues requested. The nodal temperatures and the cumulative heat flux from node to node at the end of the first time step are printed next. This process is repeated at each time step.

Finally, Figures 5-11 to 5-13 represent a comparison of the CAVE3 execution to a Grumman Thermal Analyzer execution for these three models. The solid symbols represent CAVE3 and the open ones the Thermal Analyzer. Note the execellent agreement in all cases thus establishing the validity and accuracy of CAVE3.



Total Temperature of Boundary 3000 °R

T_{aw}/T_E .95

Background Temperature for Radiation 519 °R

Emissivity 1.0

Figure 5-1. Sample Problem No. 2 Geometry Configuration

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MODEL 2A

71,151	72,152	73,153	74,154	75,155	76,156	77,157	78,158	79,159	80,160
61,141	62,142	63,143	64,144	65,145	66,146	67,147	68,148	69,149	70,150
51,131	52,132	53,133	54,134	55,135	56,136	57,137	58,138	59,139	60,140
41,121	42,122	43 123	44,124	45,125	46,126	47,127	48,128	49,129	50,130
31,111	32,112	33,113	34,114	35,115	36,116	37,117	38,118	39,119	40,120
21,101	22,102	23,103	24,104	25,105	26,106	27,107	28,108	29,109	30,110
11,91	12,92	13,93	14,94	15,95	16,96	17,97	18,98	19,99	20,100
1,81	2,82	3,83	4,84	5,85	6,86	7,87	8,88	9,89	10,90

MODEL 2B

207,255	208,256								
205,253	206,254								
203,251	204,252								
201,249	202,250								
191,239	192,240	193,241	194,242	195,243	196,244	197,245	198,246	199,247	200,248
181,229	182,230	183,231	184,232	185,233	186,234	187,235	188,236	189,237	190,238
171,219	172,220	173,221	174,222	175,223	176,224	177,225	178,226	179,227	180,228
161,209	162,210	163,211	164,212	165,213	166,214	167,215	168,216	169,217	170,218

MODEL 2C

271	272
269	270
267	268
265	266
263	264
261	262
259	260
257	258

Figure 5-2. Sample Problem No. 2 Node Configuration

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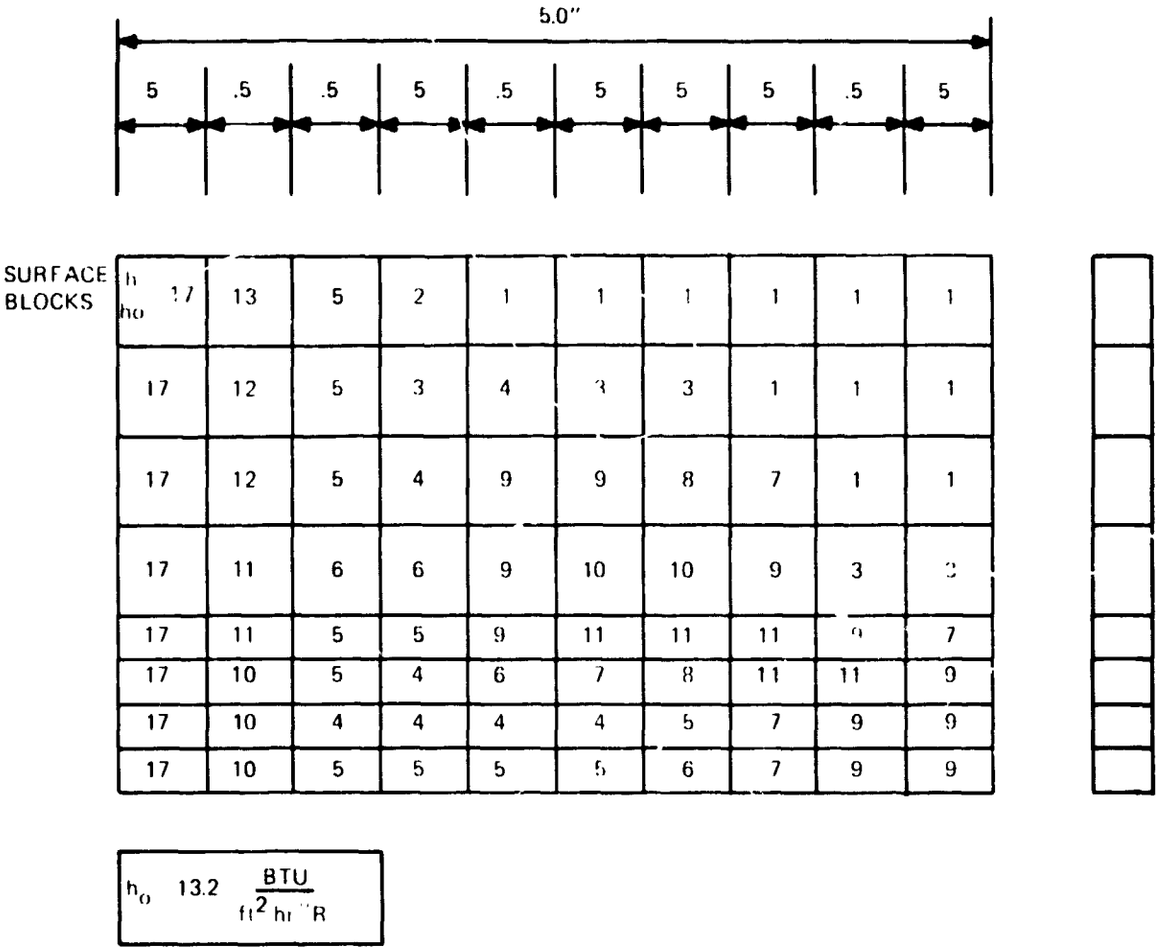


Figure 5-3. Sample Problem No. 2 Convective Heat Transfer Rates

	540 °R	860 R	1060 °R	1260 R
ρ (lbm/in^3)	0756	0756	0756	0756
Cp (BTU/lbm °R	395	511	548	562
K $\frac{BTU}{(hr\ ft^2\ ^oR/ft)}$	123 0	99 5	89.0	81 5

Figure 5-4. Physical Properties of Lockalloy

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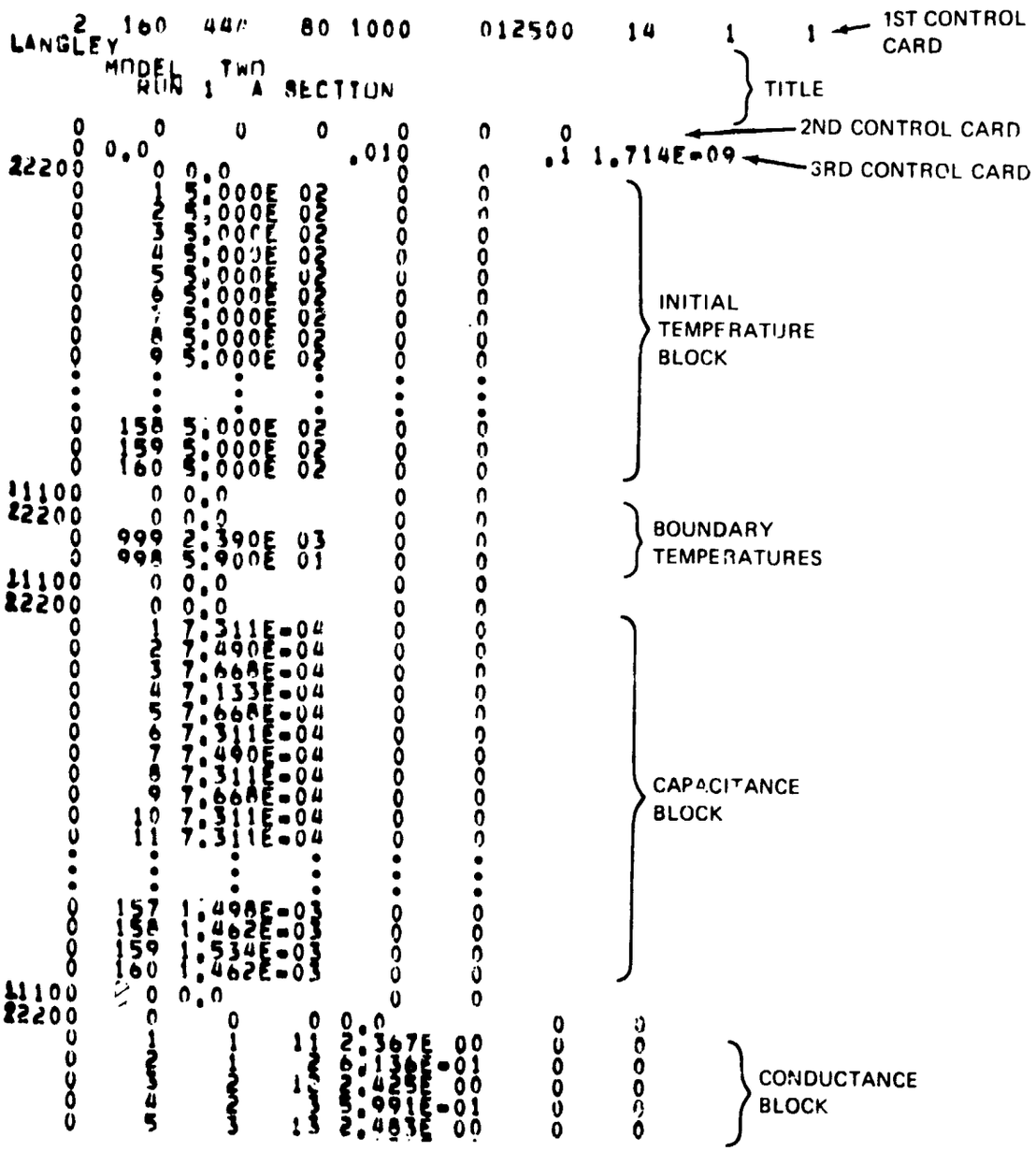


Figure 5-5. Model 2A Input (Sheet 1 of 2)

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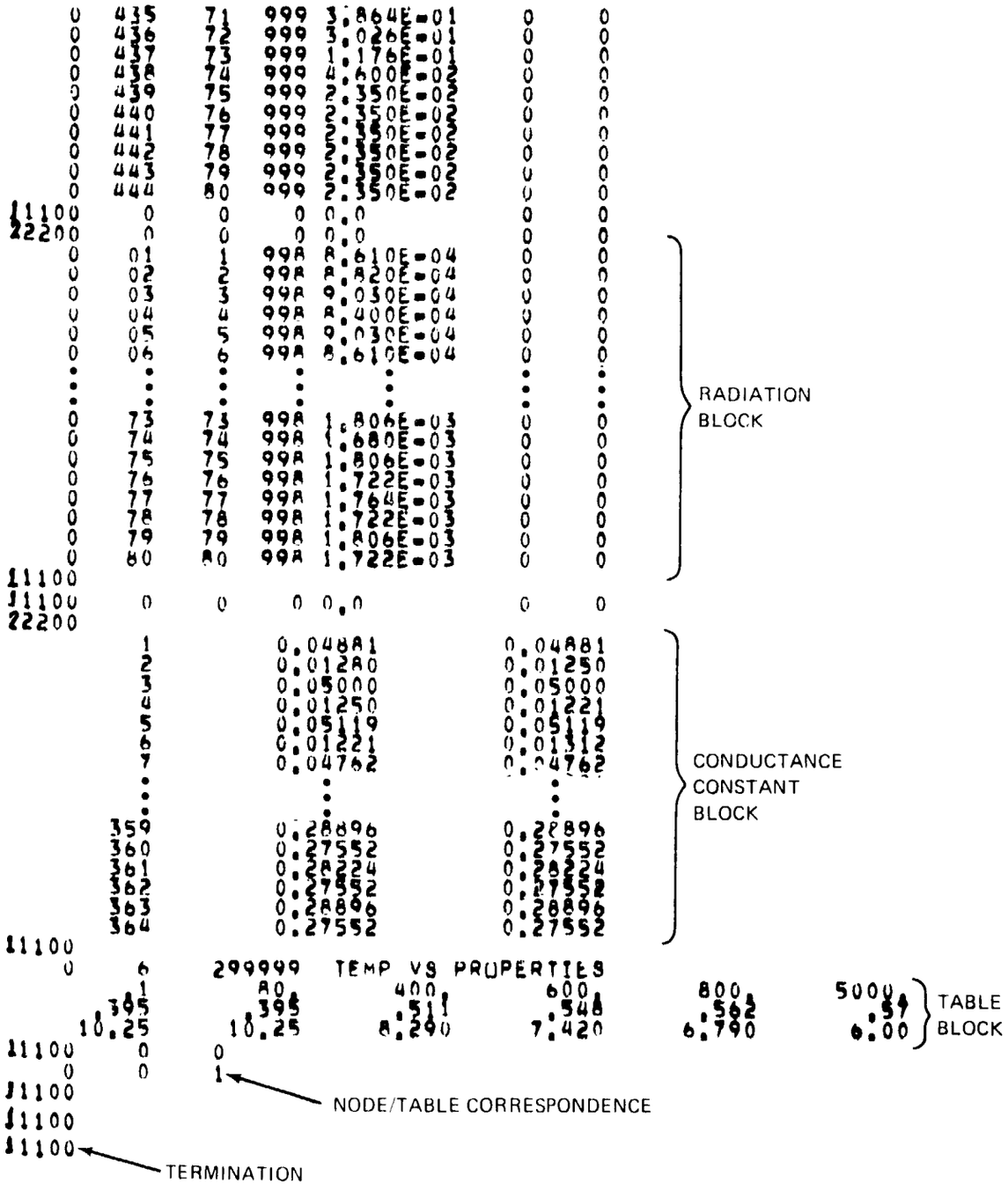


Figure 5-5. Model 2A Input (Sheet 2 of 2)

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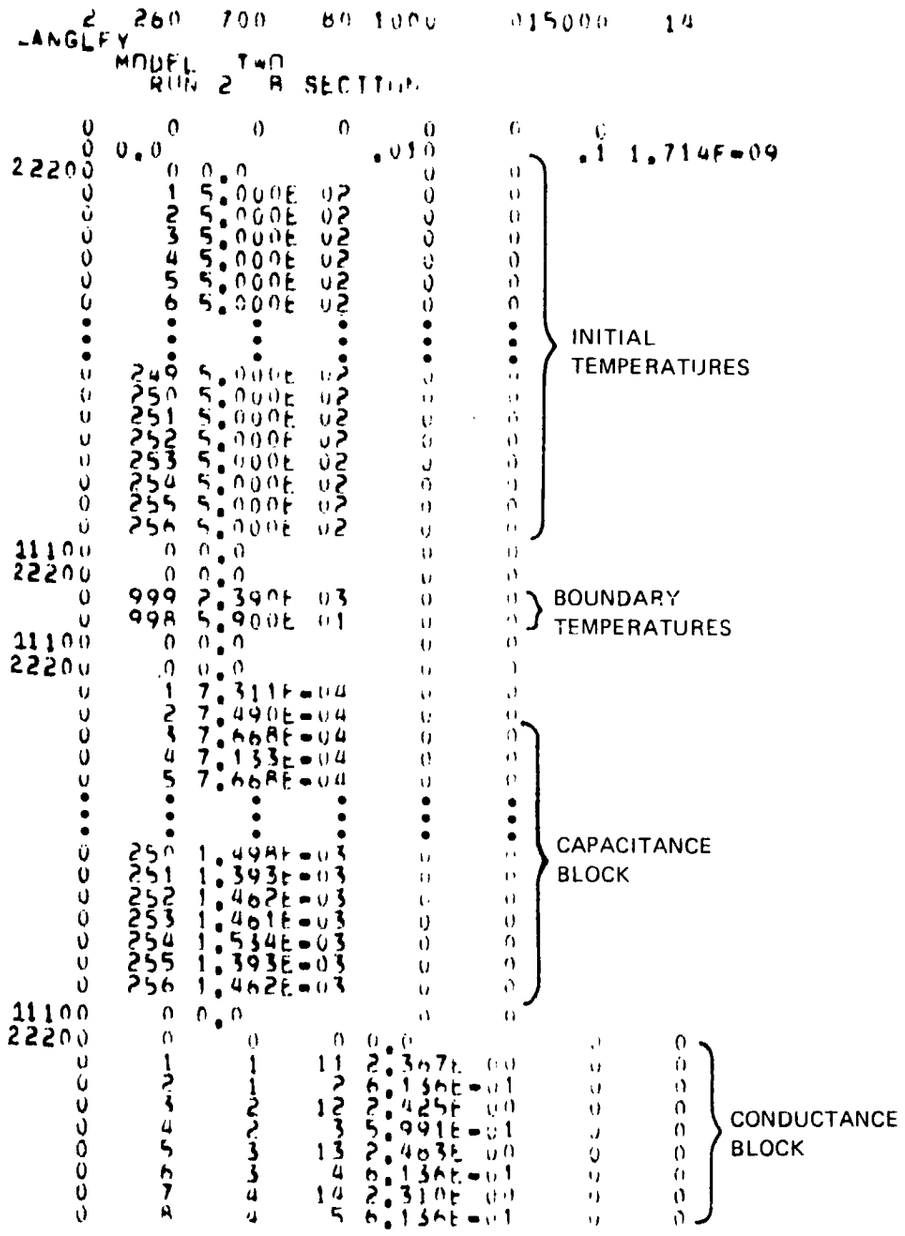


Figure 5-6. Model 2B Input (Sheet 1 of 2)

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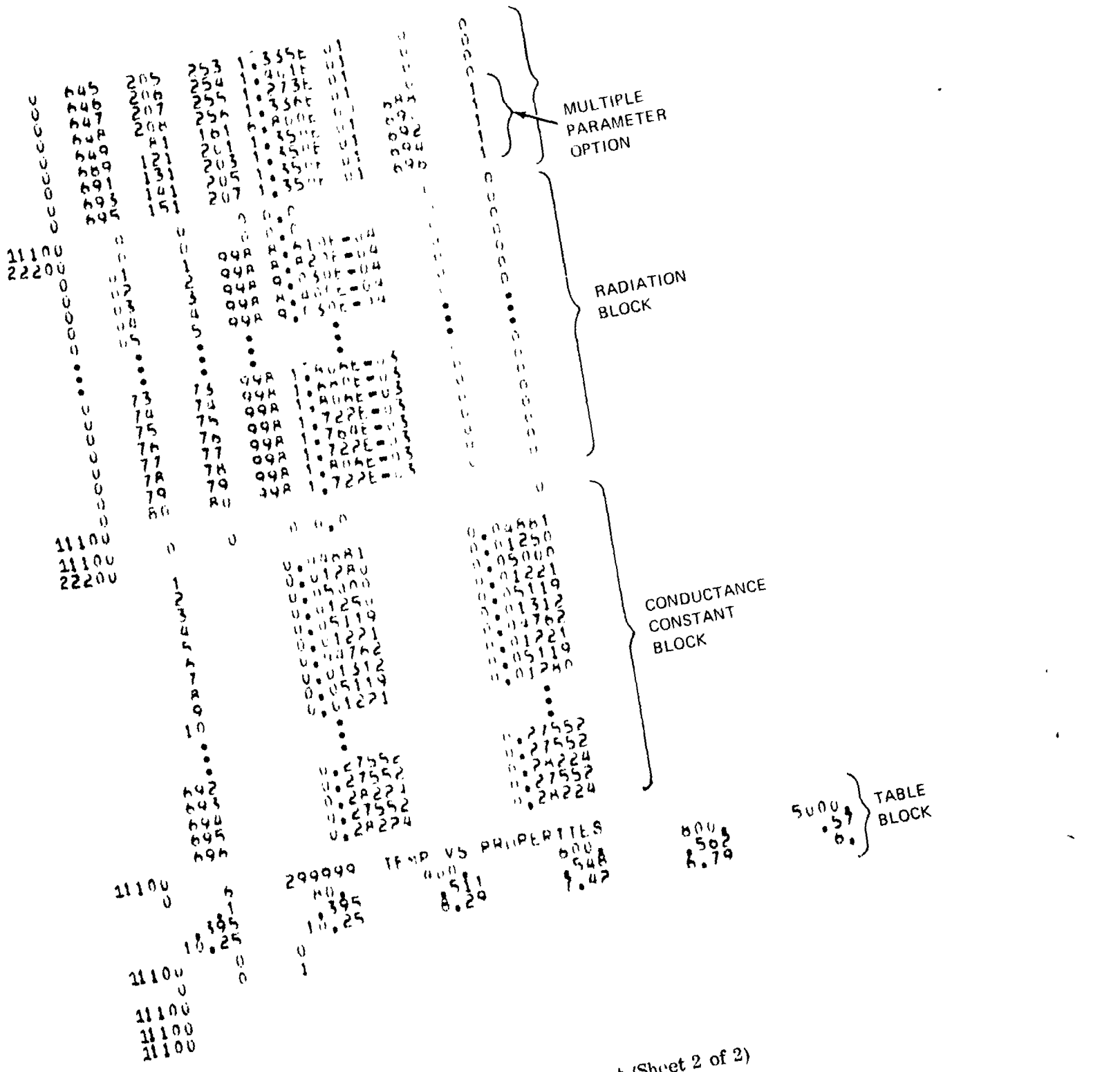


Figure 5-6. Model 2B Input (Sheet 2 of 2)

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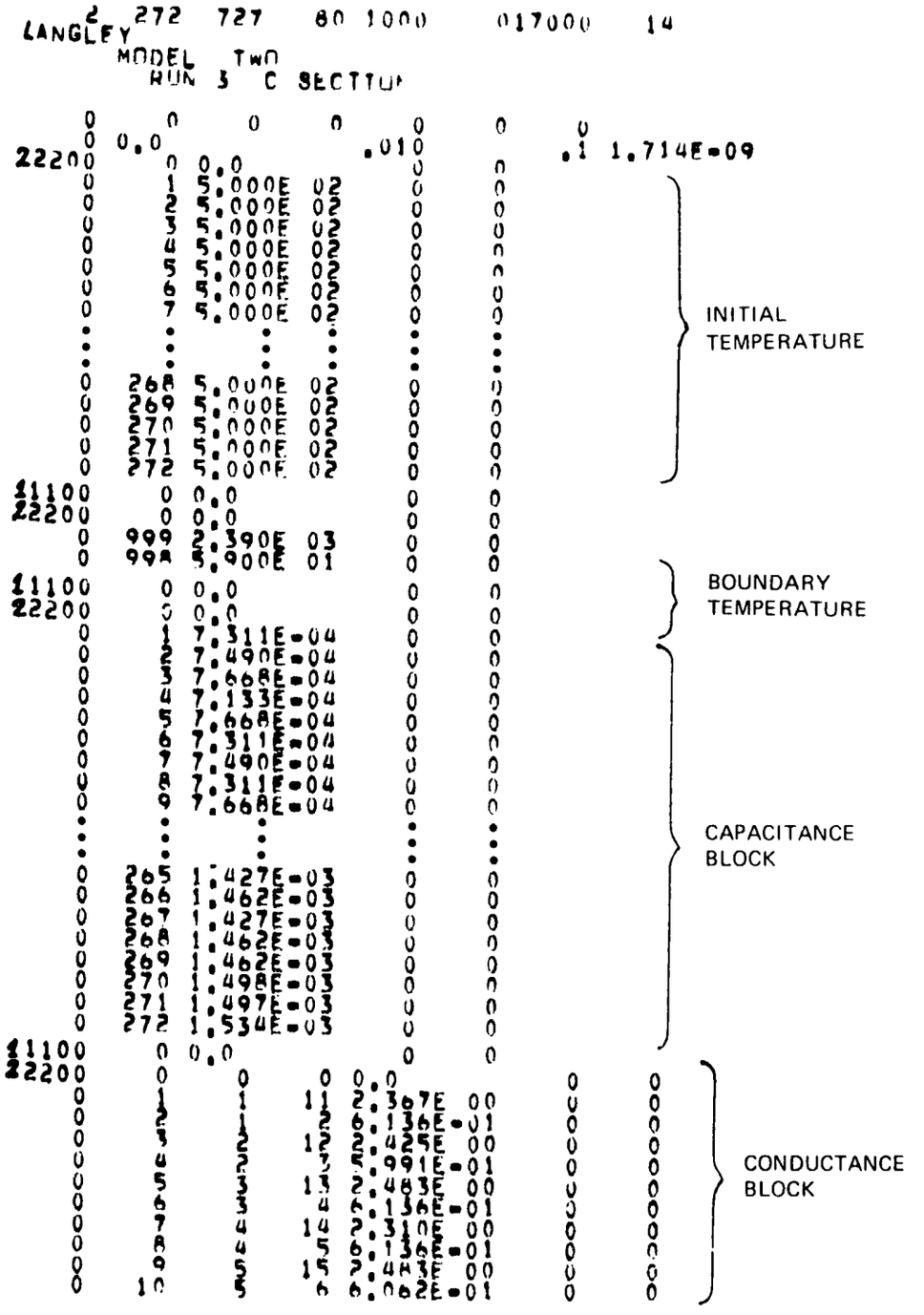


Figure 5-7. Model 2C Input (Sheet 1 of 2)

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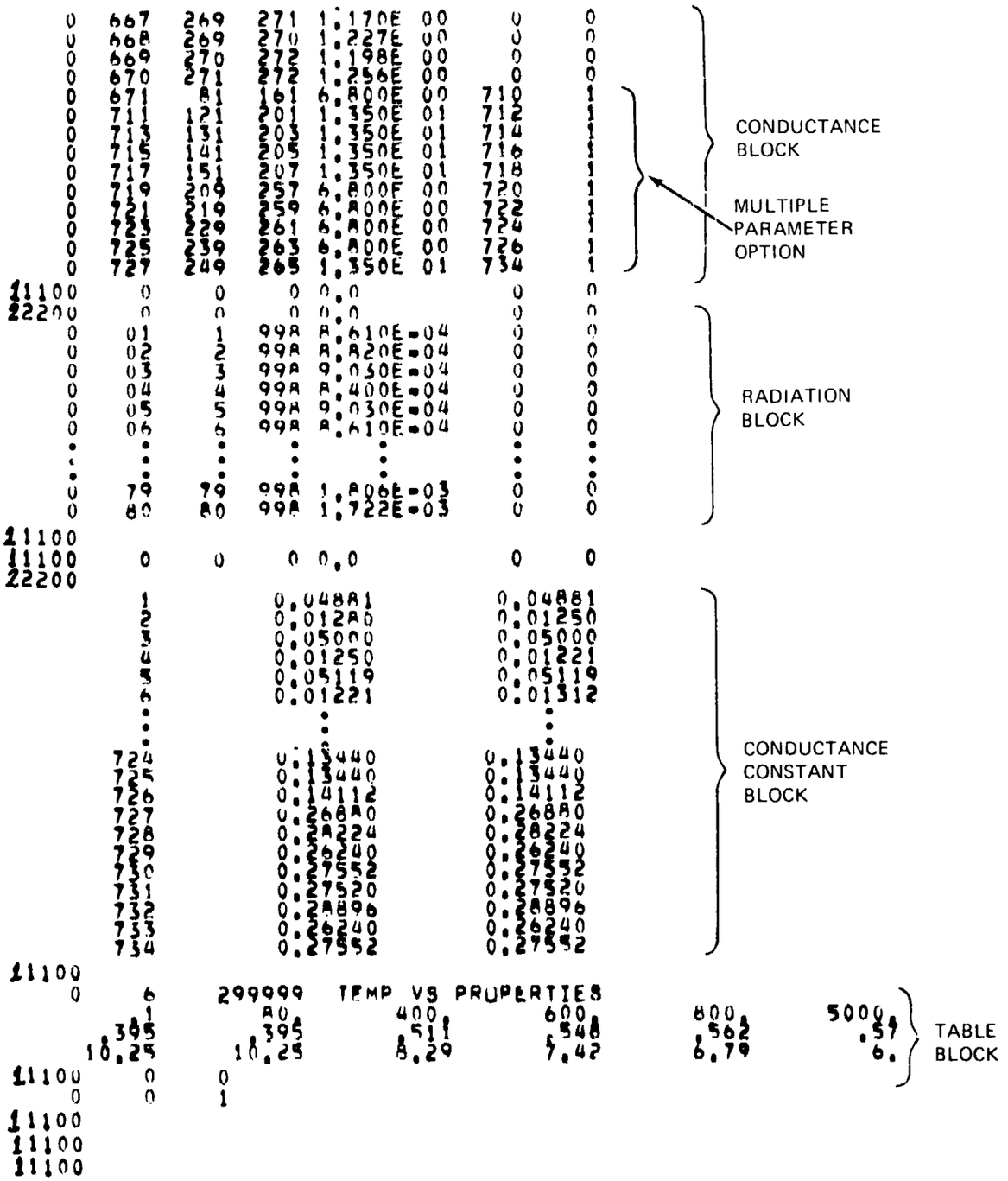


Figure 5-7. Model 2C Input (Sheet 2 of 2)

```
$STORE
NUMBND  = 2,
NUMITR  = 160,
NUMCON  = 444,
NUMTCN  = 1088,
NUMNOD  = 1000,
NUMFLX  = 0,
NSTR    = 12500,
NEVALU  = 14,
NUMTOT  = 162,
NUMSCR  = 1487,
NUMRAD  = 80,
$END
THIS RUN REQUIRES A DATA AREA OF      24015 WORDS
          1         320         162         162         444         888         162         160        1000           0
          0         162         162          80        2096         160          14        2240        1487       12500
        162         160         162         444         444         444
          1         321         483         645        1089        1977        2139        2299        3299        3299
       3299        3461        3623        3703        5799        5959        5973        8213        9700       22200
      22362       22522       22684       23128       23572
HIGHEST MEMORY IN HEXADECIMAL IS  00017740
    162     160      14     444      80    1000       0    1487   12500
```

Figure 5-8. Model 2A Output (Sheet 1 of 49)

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```
LANGLEY
      MODEL  TWO
        RUN 1  A SECTION

NUMBER OF ITERATED NODES     =    160
NUMBER OF BOUNDARY NODES     =      2
NUMBER OF CONDUCTION LINKS   =    444
NUMBER OF RADIATION LINKS    =     80
NUMBER OF HEAT SOURCES       =      0
TIME = 0.                    DTIME =  .10000000E-01      ATIME =  .10000000E+00

INITIAL TEMPERATURES OF ITERATED NODES
   T(  1) =  .500000E+03   T(  2) =  .500000E+03   T(  3) =  .500000E+03   T(  4) =  .500000E+03   T(  5) =  .500000E+03
   T(  6) =  .500000E+03   T(  7) =  .500000E+03   T(  8) =  .500000E+03   T(  9) =  .500000E+03   T( 10) =  .500000E+03
   T( 11) =  .500000E+03   T( 12) =  .500000E+03   T( 13) =  .500000E+03   T( 14) =  .500000E+03   T( 15) =  .500000E+03
   T( 16) =  .500000E+03   T( 17) =  .500000E+03   T( 18) =  .500000E+03   T( 19) =  .500000E+03   T( 20) =  .500000E+03
   T( 21) =  .500000E+03   T( 22) =  .500000E+03   T( 23) =  .500000E+03   T( 24) =  .500000E+03   T( 25) =  .500000E+03
   T( 26) =  .500000E+03   T( 27) =  .500000E+03   T( 28) =  .500000E+03   T( 29) =  .500000E+03   T( 30) =  .500000E+03
   T( 31) =  .500000E+03   T( 32) =  .500000E+03   T( 33) =  .500000E+03   T( 34) =  .500000E+03   T( 35) =  .500000E+03
   T( 36) =  .500000E+03   T( 37) =  .500000E+03   T( 38) =  .500000E+03   T( 39) =  .500000E+03   T( 40) =  .500000E+03
   T( 41) =  .500000E+03   T( 42) =  .500000E+03   T( 43) =  .500000E+03   T( 44) =  .500000E+03   T( 45) =  .500000E+03
   T( 46) =  .500000E+03   T( 47) =  .500000E+03   T( 48) =  .500000E+03   T( 49) =  .500000E+03   T( 50) =  .500000E+03
   T( 51) =  .500000E+03   T( 52) =  .500000E+03   T( 53) =  .500000E+03   T( 54) =  .500000E+03   T( 55) =  .500000E+03
   T( 56) =  .500000E+03   T( 57) =  .500000E+03   T( 58) =  .500000E+03   T( 59) =  .500000E+03   T( 60) =  .500000E+03
   T( 61) =  .500000E+03   T( 62) =  .500000E+03   T( 63) =  .500000E+03   T( 64) =  .500000E+03   T( 65) =  .500000E+03
   T( 66) =  .500000E+03   T( 67) =  .500000E+03   T( 68) =  .500000E+03   T( 69) =  .500000E+03   T( 70) =  .500000E+03
   T( 71) =  .500000E+03   T( 72) =  .500000E+03   T( 73) =  .500000E+03   T( 74) =  .500000E+03   T( 75) =  .500000E+03
   T( 76) =  .500000E+03   T( 77) =  .500000E+03   T( 78) =  .500000E+03   T( 79) =  .500000E+03   T( 80) =  .500000E+03
   T( 81) =  .500000E+03   T( 82) =  .500000E+03   T( 83) =  .500000E+03   T( 84) =  .500000E+03   T( 85) =  .500000E+03
   T( 86) =  .500000E+03   T( 87) =  .500000E+03   T( 88) =  .500000E+03   T( 89) =  .500000E+03   T( 90) =  .500000E+03
   T( 91) =  .500000E+03   T( 92) =  .500000E+03   T( 93) =  .500000E+03   T( 94) =  .500000E+03   T( 95) =  .500000E+03
   T( 96) =  .500000E+03   T( 97) =  .500000E+03   T( 98) =  .500000E+03   T( 99) =  .500000E+03   T(100) =  .500000E+03
   T(101) =  .500000E+03   T(102) =  .500000E+03   T(103) =  .500000E+03   T(104) =  .500000E+03   T(105) =  .500000E+03
   T(106) =  .500000E+03   T(107) =  .500000E+03   T(108) =  .500000E+03   T(109) =  .500000E+03   T(110) =  .500000E+03
   T(111) =  .500000E+03   T(112) =  .500000E+03   T(113) =  .500000E+03   T(114) =  .500000E+03   T(115) =  .500000E+03
   T(116) =  .500000E+03   T(117) =  .500000E+03   T(118) =  .500000E+03   T(119) =  .500000E+03   T(120) =  .500000E+03
   T(121) =  .500000E+03   T(122) =  .500000E+03   T(123) =  .500000E+03   T(124) =  .500000E+03   T(125) =  .500000E+03
   T(126) =  .500000E+03   T(127) =  .500000E+03   T(128) =  .500000E+03   T(129) =  .500000E+03   T(130) =  .500000E+03
   T(131) =  .500000E+03   T(132) =  .500000E+03   T(133) =  .500000E+03   T(134) =  .500000E+03   T(135) =  .500000E+03
   T(136) =  .500000E+03   T(137) =  .500000E+03   T(138) =  .500000E+03   T(139) =  .500000E+03   T(140) =  .500000E+03
   T(141) =  .500000E+03   T(142) =  .500000E+03   T(143) =  .500000E+03   T(144) =  .500000E+03   T(145) =  .500000E+03
   T(146) =  .500000E+03   T(147) =  .500000E+03   T(148) =  .500000E+03   T(149) =  .500000E+03   T(150) =  .500000E+03
   T(151) =  .500000E+03   T(152) =  .500000E+03   T(153) =  .500000E+03   T(154) =  .500000E+03   T(155) =  .500000E+03
   T(156) =  .500000E+03   T(157) =  .500000E+03   T(158) =  .500000E+03   T(159) =  .500000E+03   T(160) =  .500000E+03

INITIAL TEMPERATURES OF BOUNDARY NODES
   T(999) =  .234000E+04   T(998) =  .590000E+02   T(

INITIAL THERMAL CAPACITANCES OF ITERATED NODES
   CAP(  1) =  .731100E-03   CAP(  2) =  .749000E-03   CAP(  3) =  .766800E-03   CAP(  4) =  .731100E-03
   CAP(  5) =  .766800E-03   CAP(  6) =  .731100E-03   CAP(  7) =  .749000E-03   CAP(  8) =  .731100E-03
   CAP(  9) =  .766800E-03   CAP( 10) =  .731100E-03   CAP( 11) =  .731100E-03   CAP( 12) =  .749000E-03
   CAP( 13) =  .766800E-03   CAP( 14) =  .713300E-03   CAP( 15) =  .766800E-03   CAP( 16) =  .731100E-03
   CAP( 17) =  .749000E-03   CAP( 18) =  .731100E-03   CAP( 19) =  .766800E-03   CAP( 20) =  .713300E-03
   CAP( 21) =  .731100E-03   CAP( 22) =  .749000E-03   CAP( 23) =  .766800E-03   CAP( 24) =  .731100E-03
   CAP( 25) =  .766800E-03   CAP( 26) =  .731100E-03   CAP( 27) =  .749000E-03   CAP( 28) =  .731100E-03
   CAP( 29) =  .766800E-03   CAP( 30) =  .731100E-03   CAP( 31) =  .731100E-03   CAP( 32) =  .749000E-03
   CAP( 33) =  .766800E-03   CAP( 34) =  .713300E-03   CAP( 35) =  .766800E-03   CAP( 36) =  .731100E-03
   CAP( 37) =  .749000E-03   CAP( 38) =  .731100E-03   CAP( 39) =  .766800E-03   CAP( 40) =  .731100E-03
   CAP( 41) =  .146700E-02   CAP( 42) =  .149800E-02   CAP( 43) =  .153400E-02   CAP( 44) =  .146700E-02
   CAP( 45) =  .153400E-02   CAP( 46) =  .146700E-02   CAP( 47) =  .149800E-02   CAP( 48) =  .146700E-02
   CAP( 49) =  .153400E-02   CAP( 50) =  .146700E-02   CAP( 51) =  .146700E-02   CAP( 52) =  .146700E-02
   CAP( 53) =  .149700E-02   CAP( 54) =  .139300E-02   CAP( 55) =  .149700E-02   CAP( 56) =  .146700E-02
```

Figure 5-8. Model 2A Output (Sheet 2 of 49)

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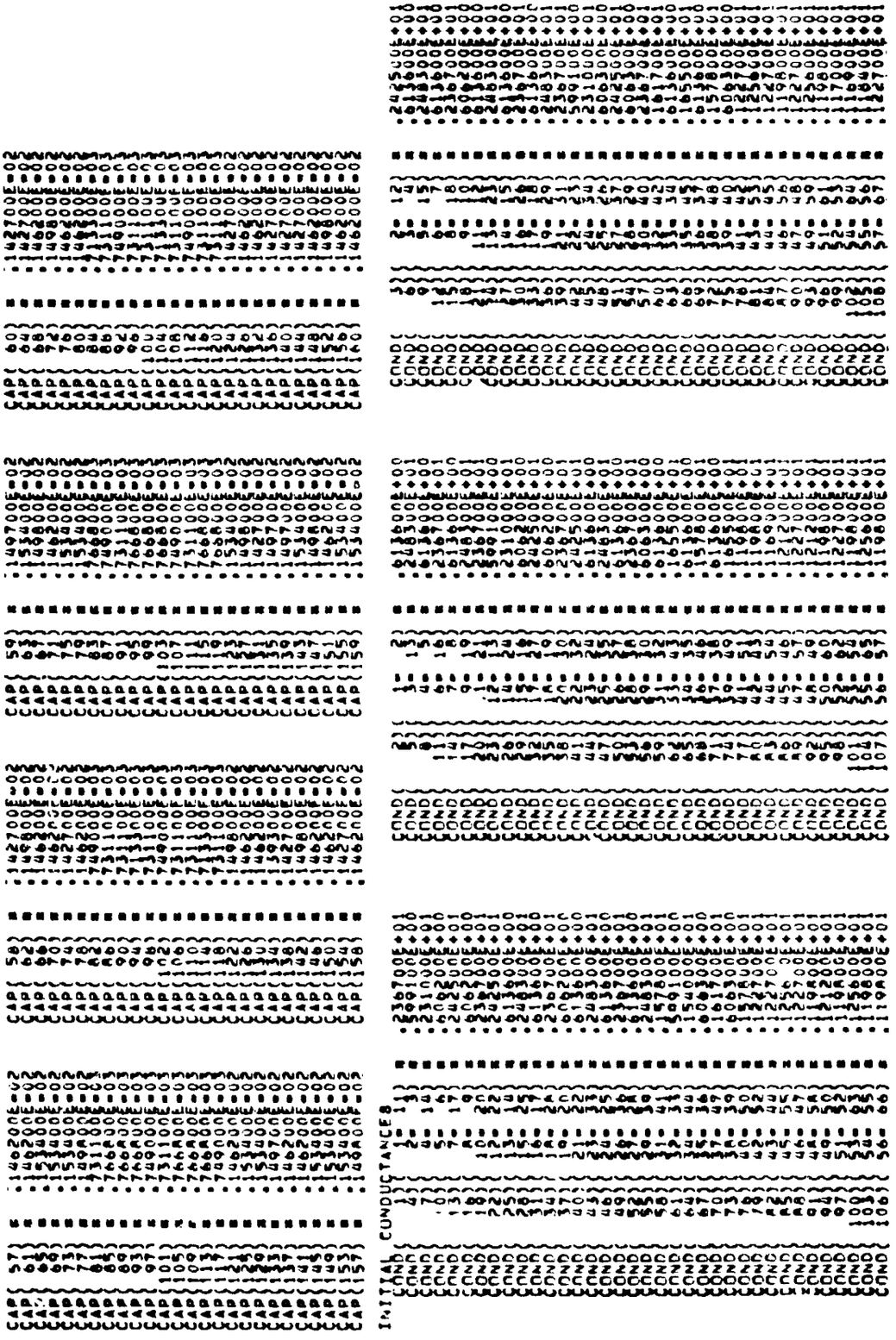


Figure 5-8. Model 2A Output (Sheet 3 of 49)

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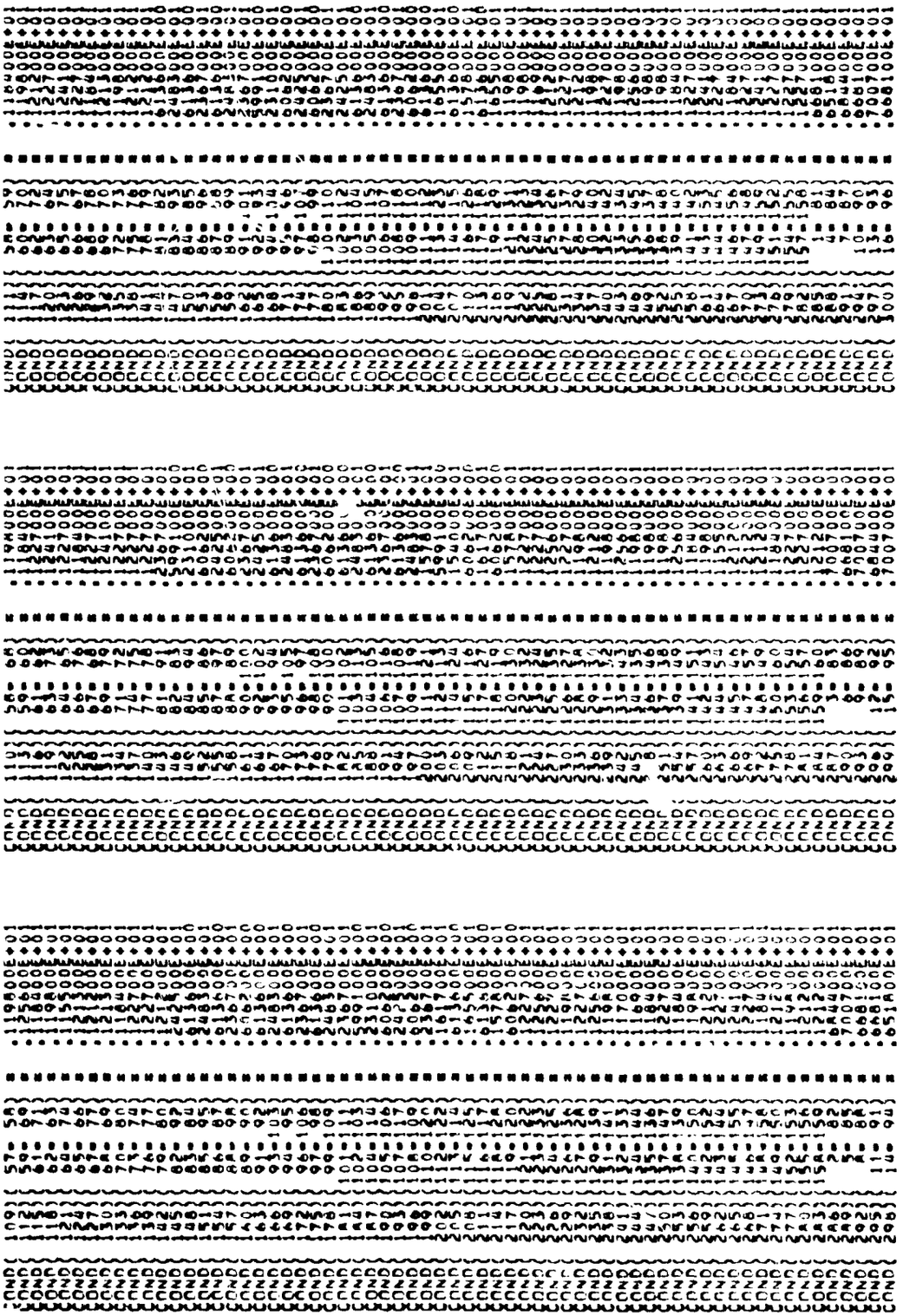


Figure 5-8. Model 2A Output (Sheet 4 of 49)

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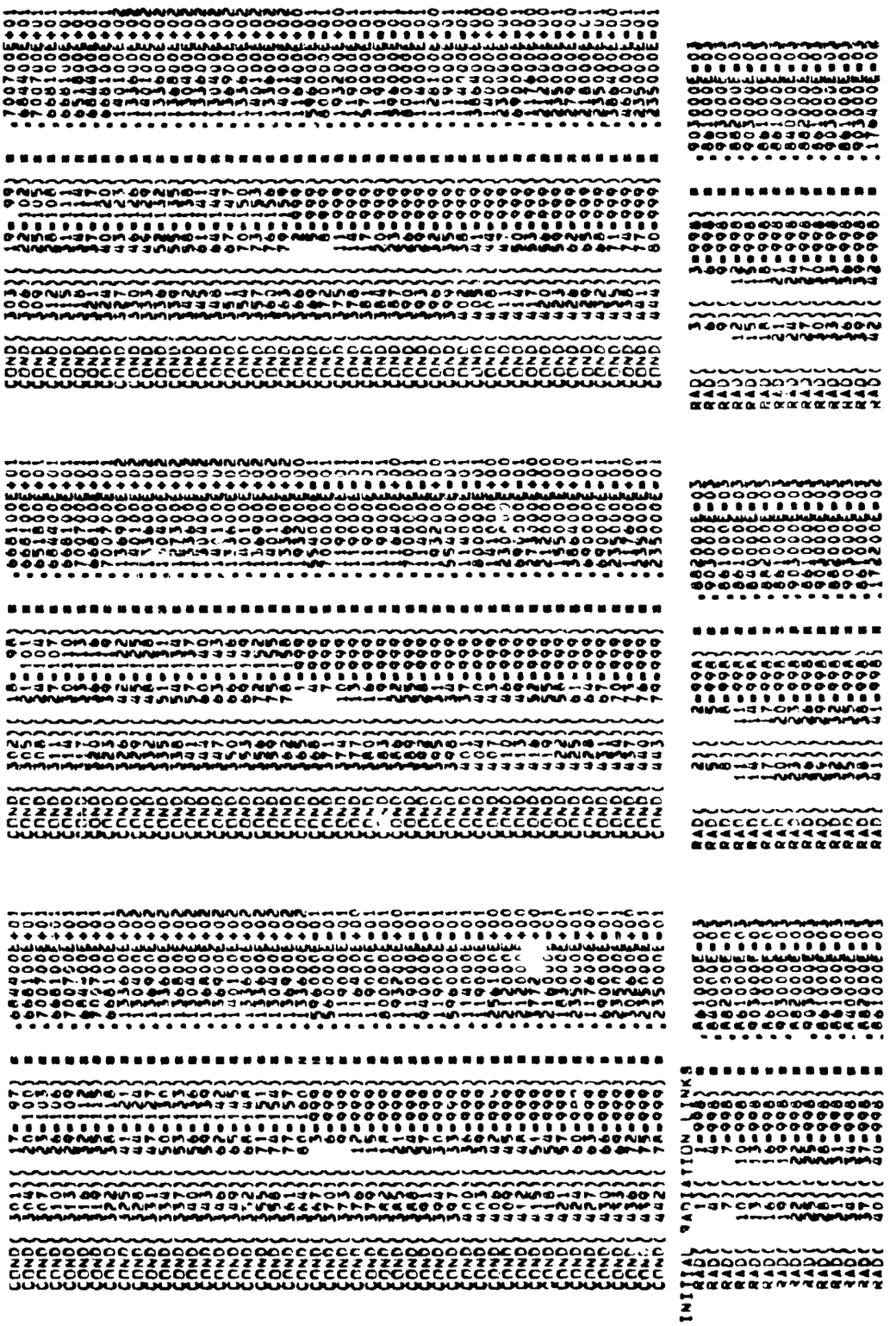


Figure 5-8. Model 2A Output (Sheet 5 of 49)

```
RAD(  43)( 43-998) =  .180600E-02    RAD(  44)( 44-998) =  .168000E-02    RAD(  45)( 45-998) =  .180600E-02
RAD(  46)( 46-998) =  .172200E-02    RAD(  47)( 47-998) =  .176400E-02    RAD(  48)( 48-998) =  .172200E-02
RAD(  49)( 49-998) =  .180600E-02    RAD(  50)( 50-998) =  .172200E-02    RAD(  51)( 51-998) =  .168100E-02
RAD(  52)( 52-998) =  .172200E-02    RAD(  53)( 53-998) =  .176400E-02    RAD(  54)( 54-998) =  .168400E-02
RAD(  55)( 55-998) =  .176300E-02    RAD(  56)( 56-998) =  .168100E-02    RAD(  57)( 57-998) =  .172200E-02
RAD(  58)( 58-998) =  .168100E-02    RAD(  59)( 59-998) =  .176300E-02    RAD(  60)( 60-998) =  .168100E-02
RAD(  61)( 61-998) =  .172200E-02    RAD(  62)( 62-998) =  .176400E-02    RAD(  63)( 63-998) =  .180600E-02
RAD(  64)( 64-998) =  .168000E-02    RAD(  65)( 65-998) =  .180600E-02    RAD(  66)( 66-998) =  .172200E-02
RAD(  67)( 67-998) =  .176400E-02    RAD(  68)( 68-998) =  .172200E-02    RAD(  69)( 69-998) =  .180600E-02
RAD(  70)( 70-998) =  .172200E-02    RAD(  71)( 71-998) =  .172200E-02    RAD(  72)( 72-998) =  .176400E-02
RAD(  73)( 73-998) =  .180600E-02    RAD(  74)( 74-998) =  .168000E-02    RAD(  75)( 75-998) =  .180600E-02
RAD(  76)( 76-998) =  .172200E-02    RAD(  77)( 77-998) =  .176400E-02    RAD(  78)( 78-998) =  .172200E-02
RAD(  79)( 79-998) =  .180600E-02    RAD(  80)( 80-998) =  .172200E-02    RAD(
```

INITIAL HEAT FLUXES

```
   1     &     2  TEMP VS PROPERTIES
         :.100000000E+00   :.400000000E+02   :.400000000E+03   :.600000000E+03   :.800000000E+03   :.500000000E+04
         :.395000000E+00   :.395000000E+00   :.511000000E+00   :.548000000E+00   :.562000000E+00   :.570000000E+00
         :.102500000E+02   :.102500000E+02   :.829000000E+01   :.742000000E+01   :.679000000E+01   :.600000000E+01
TIME=      .010
```

RESERVED STORAGE IS12500 REQUIRED IS   7269 WORDS

TBS

ROW / COL	1	2	3	4	5	6	7	8	9	10
1	2.350E+03	2.331E+03	2.298E+03	2.282E+03	2.277E+03	2.276E+03	2.277E+03	2.262E+03	2.209E+03	2.192E+03
ROW / COL	11	12	13	14	15	16	17	18	19	20
1	2.351E+03	2.331E+03	2.294E+03	2.276E+03	2.272E+03	2.272E+03	2.276E+03	2.258E+03	2.209E+03	2.195E+03
ROW / COL	21	22	23	24	25	26	27	28	29	30
1	2.351F+03	2.332E+03	2.300F+03	2.278E+03	2.280E+03	2.281E+03	2.278E+03	2.246E+03	2.211E+03	2.204E+03
ROW / COL	31	32	33	34	35	36	37	38	39	40
1	2.351F+03	2.334E+03	2.304E+03	2.288E+03	2.280E+03	2.279E+03	2.272E+03	2.247E+03	2.214E+03	2.221E+03
ROW / COL	41	42	43	44	45	46	47	48	49	50
1	2.352F+03	2.335E+03	2.308F+03	2.296E+03	2.301F+03	2.302E+03	2.294E+03	2.271E+03	2.222E+03	2.210E+03
ROW / COL	51	52	53	54	55	56	57	58	59	60
1	2.352F+03	2.336E+03	2.305E+03	2.276E+03	2.281E+03	2.281E+03	2.277E+03	2.250E+03	2.193E+03	2.175E+03
ROW / COL	61	62	63	64	65	66	67	68	69	70
1	2.352F+03	2.335F+03	2.298E+03	2.265E+03	2.243E+03	2.240E+03	2.225E+03	2.192E+03	2.164E+03	2.150E+03
ROW / COL	71	72	73	74	75	76	77	78	79	80
1	2.352F+03	2.336E+03	2.294F+03	2.252E+03	2.221E+03	2.205E+03	2.188E+03	2.167E+03	2.147E+03	2.137E+03
ROW / COL	81	82	83	84	85	86	87	88	89	90
1	2.349F+03	2.330E+03	2.296F+03	2.282E+03	2.276E+03	2.275E+03	2.275E+03	2.258E+03	2.212E+03	2.195E+03
ROW / COL	91	92	93	94	95	96	97	98	99	100
1	2.349F+03	2.330E+03	2.297F+03	2.279E+03	2.275F+03	2.274E+03	2.275E+03	2.255E+03	2.212E+03	2.198E+03
ROW / COL	101	102	103	104	105	106	107	108	109	110
1	2.349F+03	2.331E+03	2.301F+03	2.281E+03	2.280F+03	2.280E+03	2.276E+03	2.248E+03	2.214E+03	2.205E+03
ROW / COL	111	112	113	114	115	116	117	118	119	120
1	2.350F+03	2.333E+03	2.305E+03	2.288E+03	2.283F+03	2.282E+03	2.275E+03	2.250E+03	2.217E+03	2.216E+03
ROW / COL	121	122	123	124	125	126	127	128	129	130
1	2.350F+03	2.334E+03	2.306F+03	2.296E+03	2.298E+03	2.298E+03	2.289E+03	2.266E+03	2.221E+03	2.209E+03
ROW / COL	131	132	133	134	135	136	137	138	139	140
1	2.350F+03	2.335E+03	2.303E+03	2.280E+03	2.288E+03	2.287E+03	2.273E+03	2.245E+03	2.195E+03	2.177E+03
ROW / COL	141	142	143	144	145	146	147	148	149	150
1	2.350F+03	2.334E+03	2.298F+03	2.266E+03	2.246F+03	2.241E+03	2.225E+03	2.195E+03	2.166E+03	2.153E+03
ROW / COL	151	152	153	154	155	156	157	158	159	160
1	2.350E+03	2.334E+03	2.294F+03	2.254E+03	2.224E+03	2.208E+03	2.191E+03	2.169E+03	2.149E+03	2.139E+03

Figure 5-8. Model 2A Output (Sheet 6 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
ITERATION NUMBER 13  MAXIMUM ABSOLUTE ERROR =     6.30

EST ABS ERR
ROW / COL        1             2             3             4             5             6             7             8             9            10
    1          0.        -7.465E-06     5.881E-06     3.951E+00     1.174E+00     6.303E+00    -7.213E-06     1.977E-02     6.797E-02     4.883E-03
ROW / COL       11            12            13            14
    1      1.638E-05     3.417E+00     6.025E-04     7.783E-04

RAYLEIGH QUOTIENTS
ROW / COL        1             2             3             4             5             6             7             8             9            10
    1     -2.184E+01    -4.306E+01    -5.803E+01    -1.750E+02    -1.403E+02    -1.583E+02    -5.720E+01    -1.231E+02    -1.193E+02    -1.066E+02
ROW / COL       11            12            13            14
    1     -7.379E+01    -1.507E+02    -8.849E+01    -9.367E+01

DOMINANT EIGENVALUES
ROW / COL        1             2             3             4             5             6             7             8             9            10
    1     -2.184E+01    -3.805E+01    -4.306E+01    -5.720E+01    -7.379E+01    -8.849E+01    -9.367E+01    -1.066E+02    -1.193E+02    -1.231E+02
ROW / COL       11            12            13            14
    1     -1.403E+02    -1.507E+02    -1.583E+02    -1.715E+02
                    MAXIMUM ITERATION    13 IN BIJEN REACHED

TIME =    .100E-01   NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL        1             2             3             4             5             6             7             8             9            10
    1     1.812E+03     1.508E+03     1.109E+03     1.020E+03     1.001E+03     1.008E+03     1.134E+03     1.127E+03     7.434E+02     6.775E+02
ROW / COL       11            12            13            14            15            16            17            18            19            20
    1     1.810E+03     1.508E+03     1.045E+03     9.521E+02     9.381E+02     9.557E+02     1.113E+03     1.083E+03     7.484E+02     7.106E+02
ROW / COL       21            22            23            24            25            26            27            28            29            30
    1     1.808E+03     1.515E+03     1.153E+03     9.583E+02     1.035E+03     1.174E+03     1.146E+03     9.518E+02     7.682E+02     8.049E+02
ROW / COL       31            32            33            34            35            36            37            38            39            40
    1     1.805E+03     1.538E+03     1.171E+03     1.080E+03     1.044E+03     1.067E+03     1.087E+03     9.738E+02     8.135E+02     9.804E+02
ROW / COL       41            42            43            44            45            46            47            48            49            50
    1     1.801E+03     1.550E+03     1.227E+03     1.192E+03     1.326E+03     1.387E+03     1.370E+03     1.258E+03     9.190E+02     9.276E+02
ROW / COL       51            52            53            54            55            56            57            58            59            60
    1     1.801E+03     1.570E+03     1.172E+03     9.715E+02     1.275E+03     1.553E+03     1.292E+03     1.134E+03     7.497E+02     7.154E+02
ROW / COL       61            62            63            64            65            66            67            68            69            70
    1     1.807E+03     1.589E+03     1.175E+03     9.387E+02     8.236E+02     9.237E+02     9.155E+02     7.570E+02     6.414E+02     6.497E+02
ROW / COL       71            72            73            74            75            76            77            78            79            80
    1     1.820E+03     1.630E+03     1.190E+03     8.983E+02     7.074E+02     7.071E+02     7.322E+02     6.979E+02     6.594E+02     6.802E+02
ROW / COL       81            82            83            84            85            86            87            88            89            90
    1     1.707E+03     1.416E+03     1.047E+03     9.559E+02     9.355E+02     9.468E+02     1.057E+03     1.039E+03     7.444E+02     6.595E+02
ROW / COL       91            92            93            94            95            96            97            98            99           100
    1     1.705E+03     1.414E+03     1.017E+03     9.091E+02     9.063E+02     9.247E+02     1.044E+03     9.994E+02     7.206E+02     6.982E+02
ROW / COL      101           102           103           104           105           106           107           108           109           110
    1     1.702E+03     1.422E+03     1.046E+03     9.335E+02     9.671E+02     9.900E+02     1.057E+03     9.259E+02     7.474E+02     7.708E+02
ROW / COL      111           112           113           114           115           116           117           118           119           120
    1     1.699E+03     1.438E+03     1.100E+03     1.018E+03     1.015E+03     1.037E+03     1.057E+03     9.503E+02     7.932E+02     8.054E+02
ROW / COL      121           122           123           124           125           126           127           128           129           130
    1     1.694E+03     1.452E+03     1.154E+03     1.116E+03     1.231E+03     1.265E+03     1.269E+03     1.156E+03     8.352E+02     8.814E+02
ROW / COL      131           132           133           134           135           136           137           138           139           140
    1     1.693E+03     1.467E+03     1.107E+03     9.489E+02     1.170E+03     1.252E+03     1.201E+03     1.047E+03     7.208E+02     8.987E+02
ROW / COL      141           142           143           144           145           146           147           148           149           150
    1     1.700E+03     1.487E+03     1.111E+03     8.940E+02     8.040E+02     8.778E+02     8.708E+02     7.365E+02     6.245E+02     8.319E+02
ROW / COL      151           152           153           154           155           156           157           158           159           160
    1     1.715E+03     1.526E+03     1.137E+03     8.613E+02     8.903E+02     8.888E+02     7.147E+02     6.806E+02     6.426E+02     6.828E+02
```

Figure 5-8. Model 2A Output (Sheet 7 of 49)

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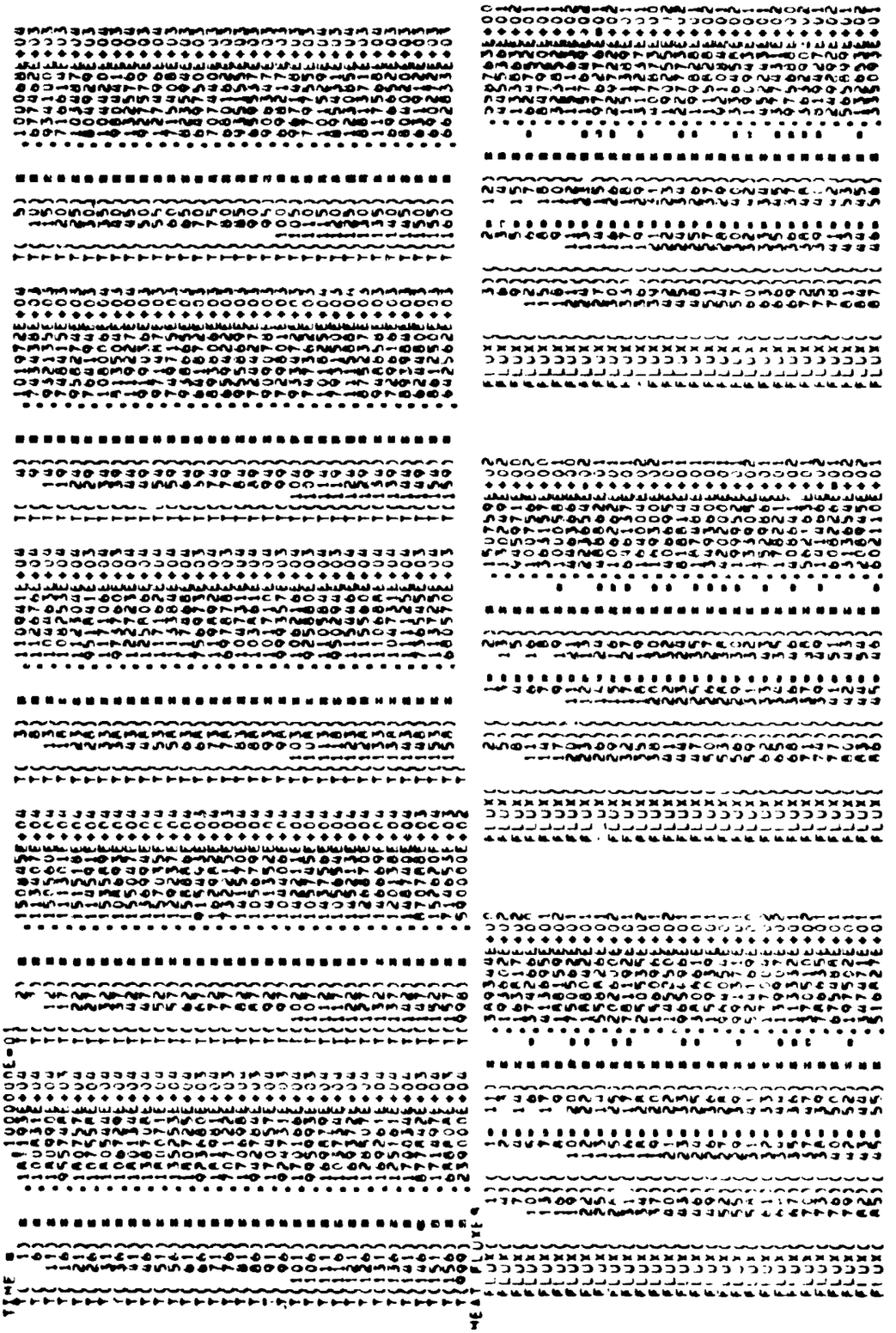


Figure 5-7. Model 2A Output (Sheet 8 of 49)

...SSIBILITY OF THE
... PAGE IS POOR

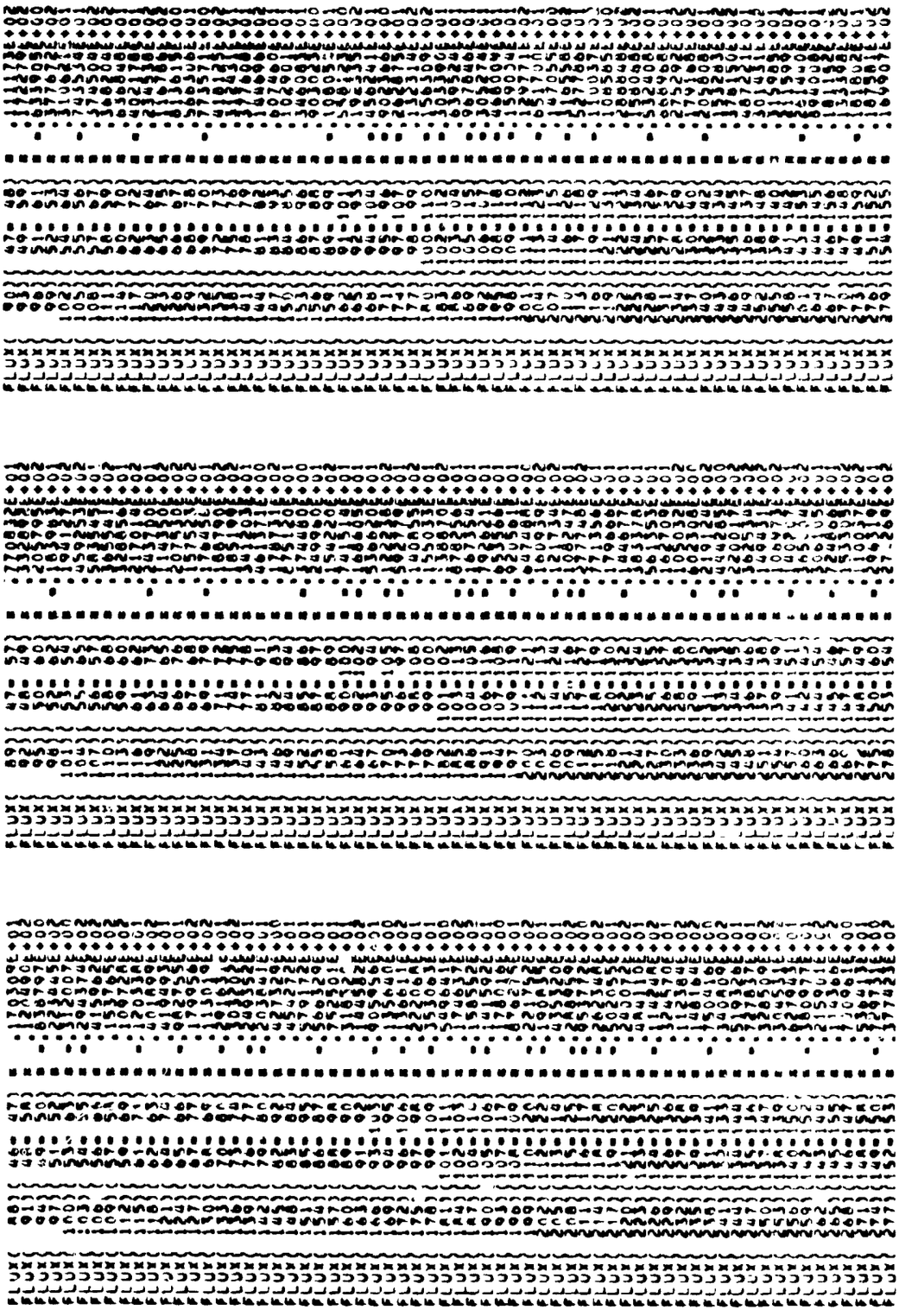


Figure 5-5. Model 2A Output (Sheet 9 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

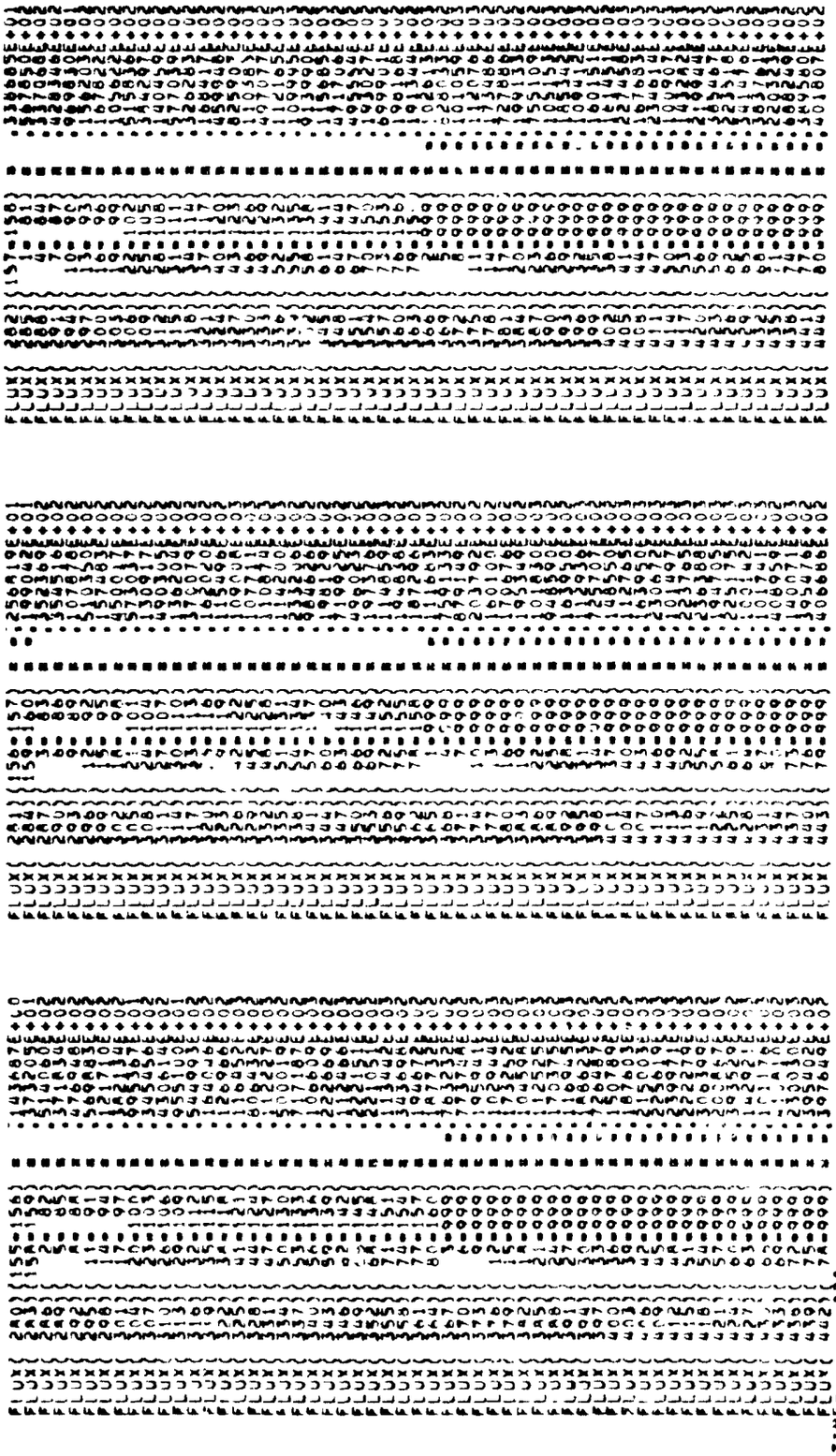


Figure 5-8. Model 2A Output (Sheet 10 of 49)

```
TSS
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1     2.133E+03   2.105E+03   2.066E+03   2.060E+03   2.065E+03   2.072E+03   2.083E+03   2.076E+03   2.005E+03   1.992E+03
ROW / COL       11          12          13          14          15          16          17          18          19          20
    1     2.134E+03   2.105E+03   2.050E+03   2.039E+03   2.048E+03   2.057E+03   2.077E+03   2.048E+03   2.005E+03   1.996E+03
ROW / COL       21          22          23          24          25          26          27          28          29          30
    1     2.135E+03   2.107E+03   2.078E+03   2.042E+03   2.065E+03   2.076E+03   2.081E+03   2.036E+03   2.005E+03   2.007E+03
ROW / COL       31          32          33          34          35          36          37          38          39          40
    1     2.136E+03   2.113E+03   2.076E+03   2.064E+03   2.053E+03   2.058E+03   2.056E+03   2.038E+03   2.010E+03   2.041E+03
ROW / COL       41          42          43          44          45          46          47          48          49          50
    1     2.137E+03   2.115E+03   2.085E+03   2.080E+03   2.097E+03   2.106E+03   2.102E+03   2.088E+03   2.026E+03   2.019E+03
ROW / COL       51          52          53          54          55          56          57          58          59          60
    1     2.138E+03   2.119E+03   2.076E+03   2.040E+03   2.093E+03   2.099E+03   2.087E+03   2.067E+03   1.998E+03   1.980E+03
ROW / COL       61          62          63          64          65          66          67          68          69          70
    1     2.137E+03   2.117E+03   2.070E+03   2.040E+03   2.010E+03   2.034E+03   2.025E+03   1.993E+03   1.970E+03   1.959E+03
ROW / COL       71          72          73          74          75          76          77          78          79          80
    1     2.135E+03   2.116E+03   2.063E+03   2.022E+03   1.993E+03   1.992E+03   1.980E+03   1.966E+03   1.953E+03   1.946E+03
ROW / COL       81          82          83          84          85          86          87          88          89          90
    1     2.131E+03   2.104E+03   2.066E+03   2.057E+03   2.062E+03   2.070E+03   2.079E+03   2.069E+03   2.009E+03   1.995E+03
ROW / COL       91          92          93          94          95          96          97          98          99         100
    1     2.132E+03   2.104E+03   2.050E+03   2.046E+03   2.054E+03   2.063E+03   2.076E+03   2.061E+03   2.009E+03   1.999E+03
ROW / COL      101         102         103         104         105         106         107         108         109         110
    1     2.132E+03   2.107E+03   2.069E+03   2.049E+03   2.061E+03   2.071E+03   2.075E+03   2.043E+03   2.009E+03   2.010E+03
ROW / COL      111         112         113         114         115         116         117         118         119         120
    1     2.134E+03   2.111E+03   2.077E+03   2.063E+03   2.061E+03   2.067E+03   2.065E+03   2.043E+03   2.015E+03   2.030E+03
ROW / COL      121         122         123         124         125         126         127         128         129         130
    1     2.135E+03   2.114E+03   2.085E+03   2.078E+03   2.062E+03   2.100E+03   2.096E+03   2.079E+03   2.026E+03   2.018E+03
ROW / COL      131         132         133         134         135         136         137         138         139         140
    1     2.136E+03   2.117E+03   2.077E+03   2.048E+03   2.045E+03   2.093E+03   2.082E+03   2.059E+03   2.000E+03   1.982E+03
ROW / COL      141         142         143         144         145         146         147         148         149         150
    1     2.135E+03   2.115E+03   2.071E+03   2.040E+03   2.025E+03   2.034E+03   2.025E+03   1.996E+03   1.972E+03   1.961E+03
ROW / COL      151         152         153         154         155         156         157         158         159         160
    1     2.134E+03   2.115E+03   2.065E+03   2.025E+03   2.001E+03   1.995E+03   1.983E+03   1.969E+03   1.955E+03   1.948E+03
ITERATION NUMBER 13  MAXIMUM ABSOLUTE ERROR =     4.25

EST 488 EHR
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1     2.197E-06  -6.918E-06   0.          0.          1.916E-05   8.518E-06  -1.742E-05  -1.322E-05   5.541E-04   8.318E-04
ROW / COL       11          12          13          14
    1     5.598E-02   2.920E-01   1.328E+00   4.254E+00

RAYLEIGH QUOTIENTS
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1    -2.123E+01  -3.504E+01  -4.054E+01  -5.285E+01  -6.730E+01  -7.977E+01  -8.343E+01  -9.615E+01  -1.065E+02  -1.099E+02
ROW / COL       11          12          13          14
    1    -1.254E+02  -1.323E+02  -1.394E+02  -1.448E+02

DOMINANT EIGENVALUES
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1    -2.123E+01  -3.504E+01  -4.054E+01  -5.285E+01  -6.730E+01  -7.977E+01  -8.343E+01  -9.615E+01  -1.065E+02  -1.099E+02
ROW / COL       11          12          13          14
    1    -1.254E+02  -1.323E+02  -1.394E+02  -1.448E+02
                  MAXIMUM ITERATION    12 IN BIJEN REACHED

TIME =    .200E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1     1.980E+03   1.789E+03   1.457E+03   1.332E+03   1.324E+03   1.353E+03   1.435E+03   1.366E+03   1.002E+03   9.061E+02
ROW / COL       11          12          13          14          15          16          17          18          19          20
    1      .981E+03   1.790E+03   1.410E+03   1.262E+03   1.269E+03   1.310E+03   1.419E+03   1.351E+03   1.007E+03   9.367E+02
ROW / COL       21          22          23          24          25          26          27          28          29          30
    1     1.985E+03   1.803E+03   1.483E+03   1.282E+03   1.359E+03   1.410E+03   1.449E+03   1.259E+03   1.052E+03   1.013E+03
ROW / COL       31          32          33          34          35          36          37          38          39          40
    1     1.989E+03   1.825E+03   1.530E+03   1.403E+03   1.365E+03   1.396E+03   1.394E+03   1.258E+03   1.066E+03   1.175E+03
```

Figure 5-8. Model 2A Output (Sheet 11 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

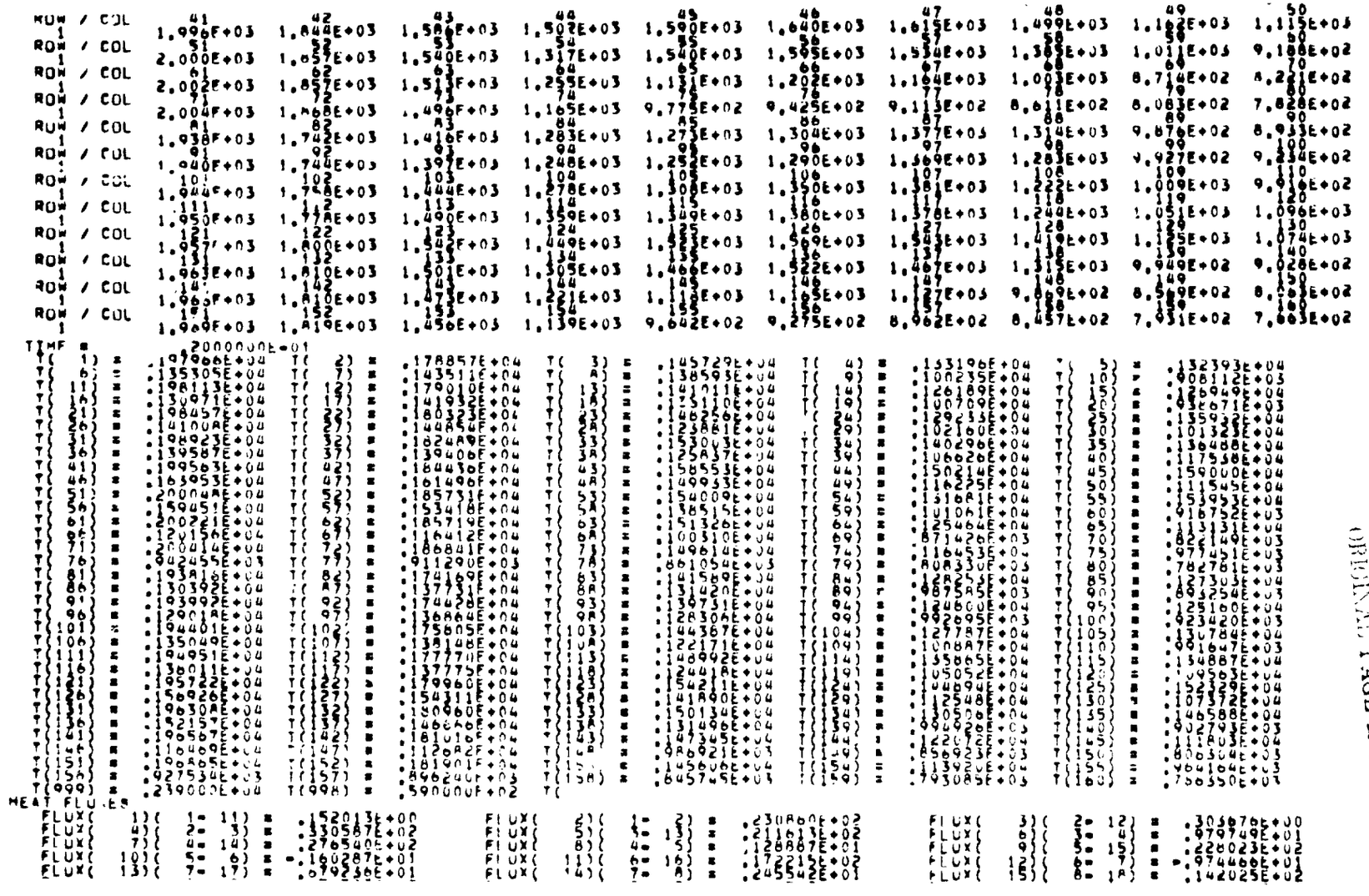


Figure 5-8. Model 2A Output (Sheet 12 of 49)

BEST AVAILABLE COPY
ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE

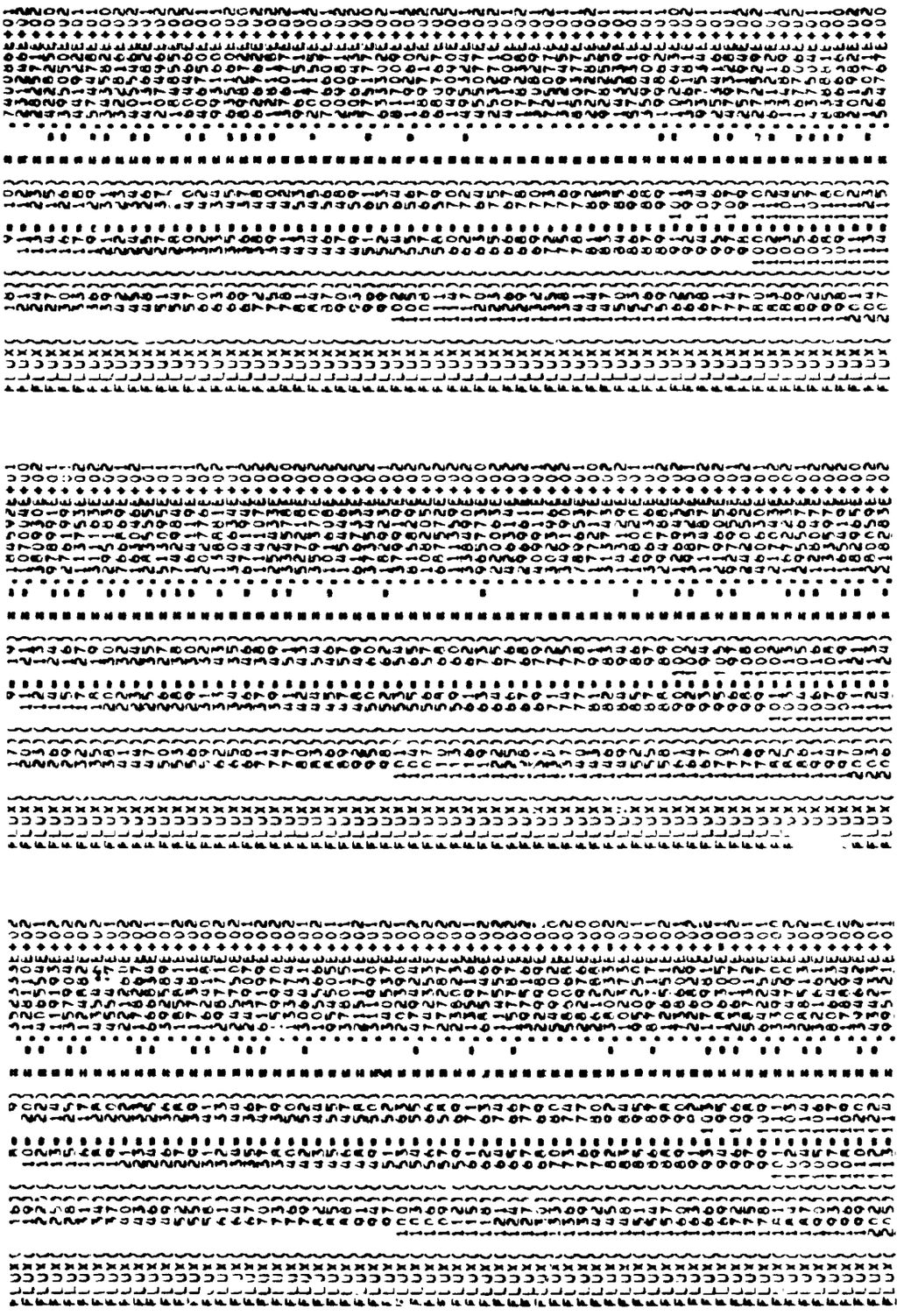


Figure 5-8. Model 2A Output (Sheet 13 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

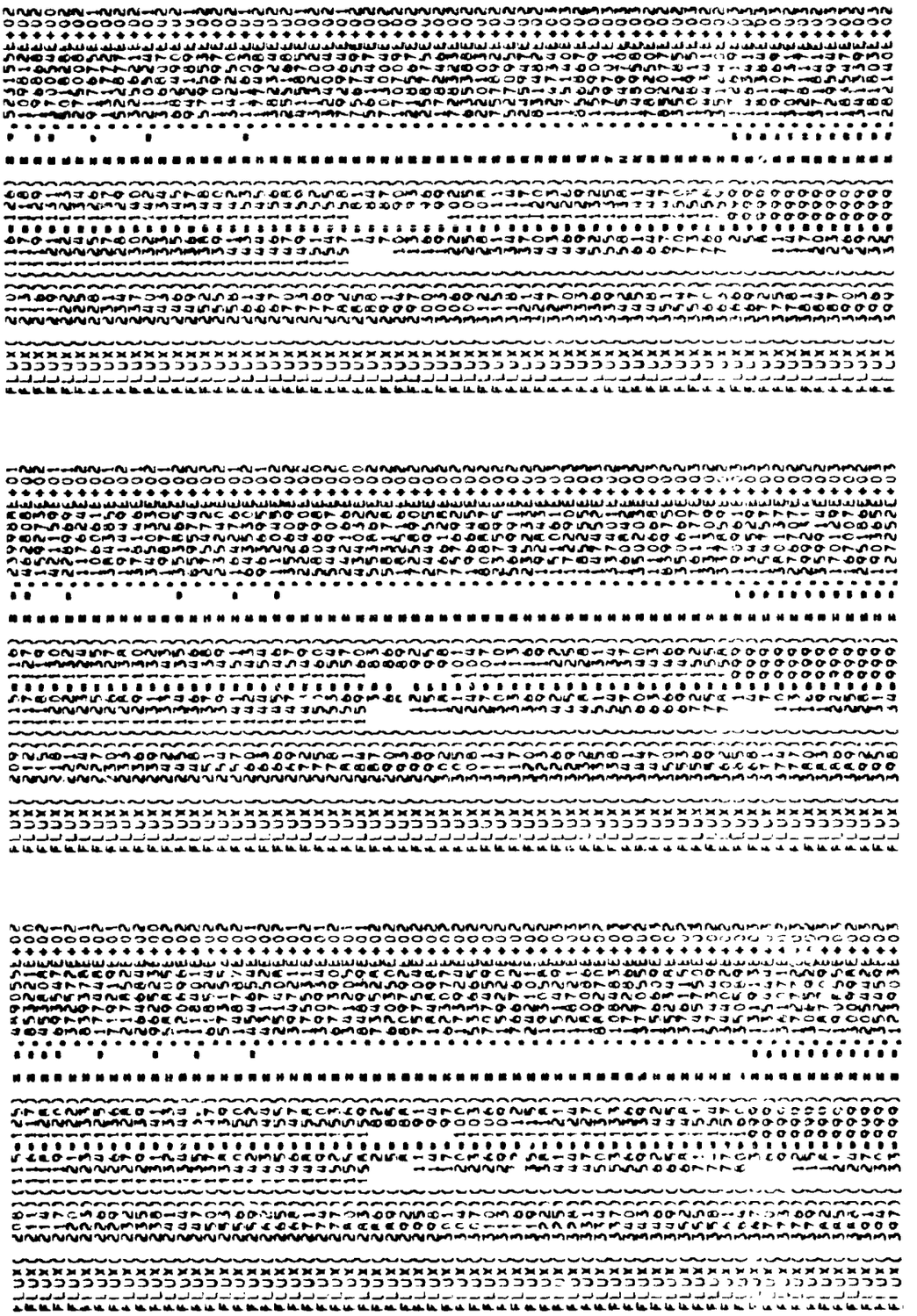


Figure 5-8. Model 2A Output (Sheet 14 of 49)

```
 FLUX( 400)( 36-999) =  .264120E+02    FLUX( 401)( 37-999) =  .262088E+02    FLUX( 402)( 38-999) =  .290457E+02
 FLUX( 403)( 39-999) =  .345128E+02    FLUX( 404)( 40-999) =  .309935E+02    FLUX( 405)( 41-999) =  .379844E+02
 FLUX( 406)( 42-999) =  .354742E+03    FLUX( 407)( 43-999) =  .277380E+03    FLUX( 408)( 44-999) =  .291982E+03
 FLUX( 409)( 45-999) =  .395220E+03    FLUX( 410)( 46-999) =  .403280E+03    FLUX( 411)( 47-999) =  .412874E+03
 FLUX( 412)( 48-999) =  .428793E+03    FLUX( 413)( 49-999) =  .186211E+03    FLUX( 414)( 50-999) =  .188851E+03
 FLUX( 415)( 51-999) =  .369207E+03    FLUX( 416)( 52-999) =  .369189E+03    FLUX( 417)( 53-999) =  .243231E+03
 FLUX( 418)( 54-999) =  .538208E+03    FLUX( 419)( 55-999) =  .416687E+03    FLUX( 420)( 56-999) =  .388587E+03
 FLUX( 421)( 57-999) =  .357481E+03    FLUX( 422)( 58-999) =  .350457E+03    FLUX( 423)( 59-999) =  .709624E+03
 FLUX( 424)( 60-999) =  .739272E+02    FLUX( 425)( 61-999) =  .375018E+03    FLUX( 426)( 62-999) =  .372173E+03
 FLUX( 427)( 63-999) =  .246027E+03    FLUX( 428)( 64-999) =  .176482E+03    FLUX( 429)( 65-999) =  .185871E+03
 FLUX( 430)( 66-999) =  .183178E+03    FLUX( 431)( 67-999) =  .186326E+03    FLUX( 432)( 68-999) =  .700685E+02
 FLUX( 433)( 69-999) =  .767675E+02    FLUX( 434)( 70-999) =  .774048E+02    FLUX( 435)( 71-999) =  .369418E+03
 FLUX( 436)( 72-999) =  .387862E+03    FLUX( 437)( 73-999) =  .245188E+03    FLUX( 438)( 74-999) =  .125197E+03
 FLUX( 439)( 75-999) =  .727351E+02    FLUX( 440)( 76-999) =  .735650E+02    FLUX( 441)( 77-999) =  .737076E+02
 FLUX( 442)( 78-999) =  .756951E+02    FLUX( 443)( 79-999) =  .778378E+02    FLUX( 444)( 80-999) =  .779504E+02
TIME=      .030

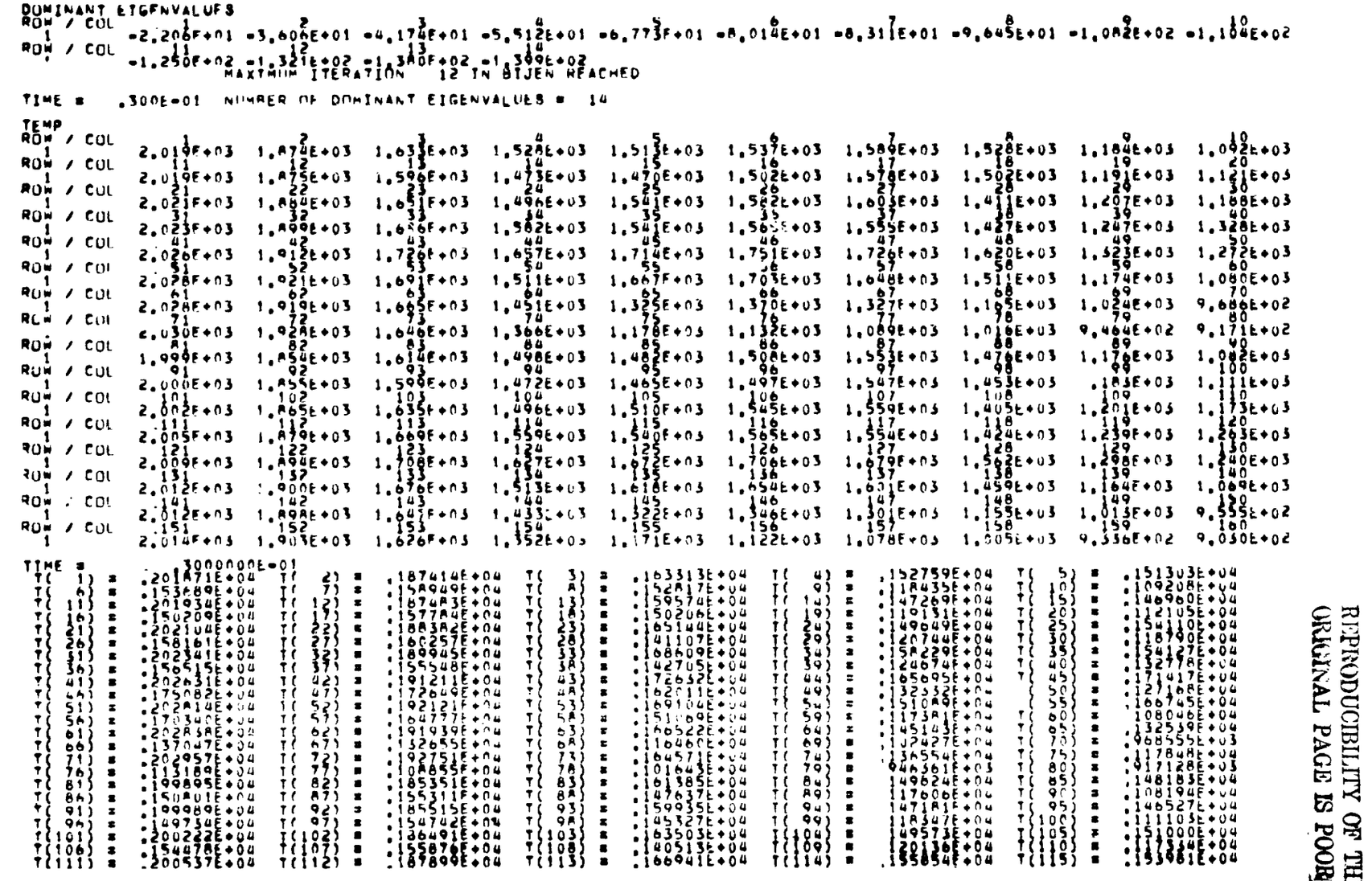
TSS
ROW / COL        1          2          3          4          5          6          7          8          9         10
   1     2.071E+03  1.998E+03  1.910E+03  1.895E+03  1.901E+03  1.912E+03  1.940E+03  1.941E+03  1.839E+03  1.825E+03
ROW / COL       11         12         13         14         15         16         17         18         19         20
   1     2.070E+03  1.998E+03  1.886E+03  1.862E+03  1.874E+03  1.890E+03  1.932E+03  1.928E+03  1.840E+03  1.833E+03
ROW / COL       21         22         23         24         25         26         27         28         29         30
   1     2.071E+03  2.001E+03  1.913E+03  1.868E+03  1.904E+03  1.924E+03  1.942E+03  1.883E+03  1.842E+03  1.853E+03
ROW / COL       31         32         33         34         35         36         37         38         39         40
   1     2.071E+03  2.008E+03  1.926E+03  1.906E+03  1.892E+03  1.904E+03  1.910E+03  1.885E+03  1.853E+03  1.905E+03
ROW / COL       41         42         43         44         45         46         47         48         49         50
   1     2.071E+03  2.017E+03  1.941E+03  1.935E+03  1.971E+03  1.991E+03  1.990E+03  1.971E+03  1.882E+03  1.880E+03
ROW / COL       51         52         53         54         55         56         57         58         59         60
   1     2.072E+03  2.020E+03  1.928E+03  1.873E+03  1.946E+03  1.985E+03  1.972E+03  1.942E+03  1.841E+03  1.824E+03
ROW / COL       61         62         63         64         65         66         67         68         69         70
   1     2.072E+03  2.021E+03  1.926E+03  1.876E+03  1.850E+03  1.883E+03  1.879E+03  1.838E+03  1.809E+03  1.802E+03
ROW / COL       71         72         73         74         75         76         77         78         79         80
   1     2.073E+03  2.030E+03  1.926E+03  1.857E+03  1.821E+03  1.822E+03  1.819E+03  1.807E+03  1.796E+03  1.793E+03
ROW / COL       81         82         83         84         85         86         87         88         89         90
   1     2.064E+03  1.997E+03  1.912E+03  1.891E+03  1.897E+03  1.910E+03  1.935E+03  1.929E+03  1.846E+03  1.830E+03
ROW / COL       91         92         93         94         95         96         97         98         99        100
   1     2.064E+03  1.997E+03  1.901E+03  1.874E+03  1.885E+03  1.900E+03  1.931E+03  1.918E+03  1.846E+03  1.838E+03
ROW / COL      101        102        103        104        105        106        107        108        109        110
   1     2.065E+03  2.000E+03  1.916E+03  1.880E+03  1.900E+03  1.918E+03  1.933E+03  1.893E+03  1.849E+03  1.857E+03
ROW / COL      111        112        113        114        115        116        117        118        119        120
   1     2.065E+03  2.004E+03  1.929E+03  1.905E+03  1.905E+03  1.918E+03  1.923E+03  1.897E+03  1.860E+03  1.889E+03
ROW / COL      121        122        123        124        125        126        127        128        129        130
   1     2.066E+03  2.011E+03  1.943E+03  1.932E+03  1.963E+03  1.981E+03  1.980E+03  1.957E+03  1.882E+03  1.877E+03
ROW / COL      131        132        133        134        135        136        137        138        139        140
   1     2.067E+03  2.016E+03  1.952E+03  1.887E+03  1.954E+03  1.975E+03  1.963E+03  1.931E+03  1.847E+03  1.828E+03
ROW / COL      141        142        143        144        145        146        147        148        149        150
   1     2.067E+03  2.018E+03  1.930E+03  1.878E+03  1.859E+03  1.883E+03  1.879E+03  1.843E+03  1.813E+03  1.804E+03
ROW / COL      151        152        153        154        155        156        157        158        159        160
   1     2.069E+03  2.025E+03  1.928E+03  1.862E+03  1.826E+03  1.826E+03  1.823E+03  1.810E+03  1.798E+03  1.794E+03
ITERATION NUMBER 13  MAXIMUM ABSOLUTE ERROR =      .840

EST ABS ERR
ROW / COL        1          2          3          4          5          6          7          8          9         10
   1    -3.879E-06 -4.099E-05  4.157E-06  5.007E-06  7.849E-06  1.307E-05 -8.694E-06  2.294E-05  1.746E-04  1.326E-04
ROW / COL       11         12         13         14
   1     2.606E-02  6.176E-02  8.403E-01  5.719E-01

RAYLEIGH QUOTIENTS
ROW / COL        1          2          3          4          5          6          7          8          9         10
   1    -2.206E+01 -3.406E+01 -4.174E+01 -5.512E+01 -6.773E+01 -8.014E+01 -8.311E+01 -9.645E+01 -1.082E+02 -1.104E+02
ROW / COL       11         12         13         14
   1    -1.250E+02 -1.321E+02 -1.340E+02 -1.399E+02
```

Figure 5-8. Model 2A Output (Sheet 15 of 49)

Approved for Public Release



```
DOMINANT EIGENVALUES
ROW / COL      1           2           3           4           5           6           7           8           9          10
    1  -2.206E+01  -3.606E+01  -4.174E+01  -5.512E+01  -6.773E+01  -8.014E+01  -8.311E+01  -9.645E+01  -1.082E+02  -1.104E+02
ROW / COL     11          12          13          14
    1  -1.250E+02  -1.321E+02  -1.340E+02  -1.399E+02
                MAXIMUM ITERATION   12 IN BIJEN REACHED

TIME =   .300E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL      1           2           3           4           5           6           7           8           9          10
    1   2.019E+03   1.874E+03   1.635E+03   1.528E+03   1.513E+03   1.537E+03   1.589E+03   1.528E+03   1.184E+03   1.092E+03
ROW / COL     11          12          13          14          15          16          17          18          19          20
    1   2.019E+03   1.875E+03   1.596E+03   1.473E+03   1.470E+03   1.502E+03   1.578E+03   1.502E+03   1.191E+03   1.121E+03
ROW / COL     21          22          23          24          25          26          27          28          29          30
    1   2.021E+03   1.884E+03   1.651E+03   1.496E+03   1.541E+03   1.582E+03   1.603E+03   1.411E+03   1.207E+03   1.188E+03
ROW / COL     31          32          33          34          35          36          37          38          39          40
    1   2.023E+03   1.899E+03   1.686E+03   1.582E+03   1.541E+03   1.585E+03   1.555E+03   1.427E+03   1.247E+03   1.328E+03
ROW / COL     41          42          43          44          45          46          47          48          49          50
    1   2.026E+03   1.912E+03   1.720E+03   1.657E+03   1.714E+03   1.751E+03   1.726E+03   1.620E+03   1.523E+03   1.272E+03
ROW / COL     51          52          53          54          55          56          57          58          59          60
    1   2.028E+03   1.921E+03   1.691E+03   1.511E+03   1.667E+03   1.703E+03   1.648E+03   1.511E+03   1.174E+03   1.080E+03
ROW / COL     61          62          63          64          65          66          67          68          69          70
    1   2.028E+03   1.919E+03   1.665E+03   1.451E+03   1.325E+03   1.370E+03   1.327E+03   1.195E+03   1.024E+03   9.686E+02
ROW / COL     71          72          73          74          75          76          77          78          79          80
    1   2.030E+03   1.922E+03   1.646E+03   1.366E+03   1.178E+03   1.132E+03   1.089E+03   1.016E+03   9.464E+02   9.171E+02
ROW / COL     81          82          83          84          85          86          87          88          89          90
    1   1.998E+03   1.854E+03   1.614E+03   1.498E+03   1.488E+03   1.508E+03   1.553E+03   1.470E+03   1.176E+03   1.082E+03
ROW / COL     91          92          93          94          95          96          97          98          99         100
    1   2.000E+03   1.855E+03   1.590E+03   1.472E+03   1.465E+03   1.497E+03   1.547E+03   1.453E+03   .183E+03   1.111E+03
ROW / COL    101         102         103         104         105         106         107         108         109         110
    1   2.002E+03   1.865E+03   1.635E+03   1.496E+03   1.510F+03   1.545E+03   1.559E+03   1.405E+03   1.201E+03   1.173E+03
ROW / COL    111         112         113         114         115         116         117         118         119         120
    1   2.005E+03   1.879E+03   1.669E+03   1.559E+03   1.540F+03   1.565E+03   1.554E+03   1.424E+03   1.239F+03   1.203E+03
ROW / COL    121         122         123         124         125         126         127         128         129         130
    1   2.009E+03   1.894E+03   1.708E+03   1.627E+03   1.672E+03   1.706E+03   1.679E+03   1.562E+03   1.298E+03   1.240E+03
ROW / COL    131         132         133         134         135         136         137         138         139         140
    1   2.012E+03   1.900E+03   1.676E+03   1.513E+03   1.618E+03   1.654E+03   1.601E+03   1.459E+03   1.164E+03   1.069E+03
ROW / COL    141         142         143         144         145         146         147         148         149         150
    1   2.012E+03   1.898E+03   1.647F+03   1.433E+03   1.322E+03   1.346E+03   1.301E+03   1.155E+03   1.013E+03   9.555E+02
ROW / COL    151         152         153         154         155         156         157         158         159         160
    1   2.014E+03   1.903E+03   1.626F+03   1.352E+03   1.171E+03   1.122E+03   1.078E+03   1.005E+03   9.336E+02   9.030E+02

TIME =   .30000000E-01
 T(   1) =  .201A71E+04   T(   2) =  .187414E+04   T(   3) =  .163313E+04   T(   4) =  .152759E+04   T(   5) =  .151303E+04
 T(   6) =  .153689E+04   T(   7) =  .158A94E+04   T(   8) =  .152A17E+04   T(   9) =  .11R435E+04   T(  10) =  .109208E+04
 T(  11) =  .201934E+04   T(  12) =  .187AA3E+04   T(  13) =  .159574E+04   T(  14) =  .147269E+04   T(  15) =  .146960E+04
 T(  16) =  .150209E+04   T(  17) =  .157748E+04   T(  18) =  .150206E+04   T(  19) =  .119131E+04   T(  20) =  .112105E+04
 T(  21) =  .202104E+04   T(  22) =  .188A3A2E+04   T(  23) =  .165144E+04   T(  24) =  .149649E+04   T(  25) =  .154110E+04
 T(  26) =  .158161E+04   T(  27) =  .160257E+04   T(  28) =  .141107E+04   T(  29) =  .120744E+04   T(  30) =  .118700E+04
 T(  31) =  .202341E+04   T(  32) =  .189045E+04   T(  33) =  .168609E+04   T(  34) =  .15R229E+04   T(  35) =  .154167E+04
 T(  36) =  .156515E+04   T(  37) =  .155548E+04   T(  38) =  .142705E+04   T(  39) =  .124674E+04   T(  40) =  .132778E+04
 T(  41) =  .202A31E+04   T(  42) =  .191211E+04   T(  43) =  .172653E+04   T(  44) =  .165695E+04   T(  45) =  .171417E+04
 T(  46) =  .175082E+04   T(  47) =  .172649E+04   T(  48) =  .162011E+04   T(  49) =  .132532E+04   T(  50) =  .127168E+04
 T(  51) =  .202A14E+04   T(  52) =  .192121E+04   T(  53) =  .169104E+04   T(  54) =  .151088E+04   T(  55) =  .166745E+04
 T(  56) =  .178340E+04   T(  57) =  .184777E+04   T(  58) =  .151169E+04   T(  59) =  .117381E+04   T(  60) =  .108046E+04
 T(  61) =  .202A5AE+04   T(  62) =  .191939E+04   T(  63) =  .166522E+04   T(  64) =  .145143E+04   T(  65) =  .132539E+04
 T(  66) =  .137047E+04   T(  67) =  .152655E+04   T(  68) =  .116460E+04   T(  69) =  .102427E+04   T(  70) =  .968555E+03
 T(  71) =  .202957E+04   T(  72) =  .192751E+04   T(  73) =  .164571E+04   T(  74) =  .136554E+04   T(  75) =  .117848E+04
 T(  76) =  .115189E+04   T(  77) =  .108855E+04   T(  78) =  .101643E+04   T(  79) =  .946361E+03   T(  80) =  .917128E+03
 T(  81) =  .199805E+04   T(  82) =  .185351E+04   T(  83) =  .161385E+04   T(  84) =  .149624E+04   T(  85) =  .148183E+04
 T(  86) =  .150A01E+04   T(  87) =  .155211E+04   T(  88) =  .147637E+04   T(  89) =  .117606E+04   T(  90) =  .108194E+04
 T(  91) =  .199988E+04   T(  92) =  .185515E+04   T(  93) =  .159935E+04   T(  94) =  .147181E+04   T(  95) =  .146527E+04
 T(  96) =  .149734E+04   T(  97) =  .154742E+04   T(  98) =  .145327E+04   T(  99) =  .118347E+04   T( 100) =  .111103E+04
 T( 101) =  .200222E+04   T( 102) =  .186491E+04   T( 103) =  .163503E+04   T( 104) =  .149573E+04   T( 105) =  .151000E+04
 T( 106) =  .154478E+04   T( 107) =  .155870E+04   T( 108) =  .140513E+04   T( 109) =  .120136E+04   T( 110) =  .117344E+04
 T( 111) =  .200537E+04   T( 112) =  .187809E+04   T( 113) =  .166941E+04   T( 114) =  .155854E+04   T( 115) =  .153961E+04
```

Figure 5-8. Model 2A Output (Sheet 16 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

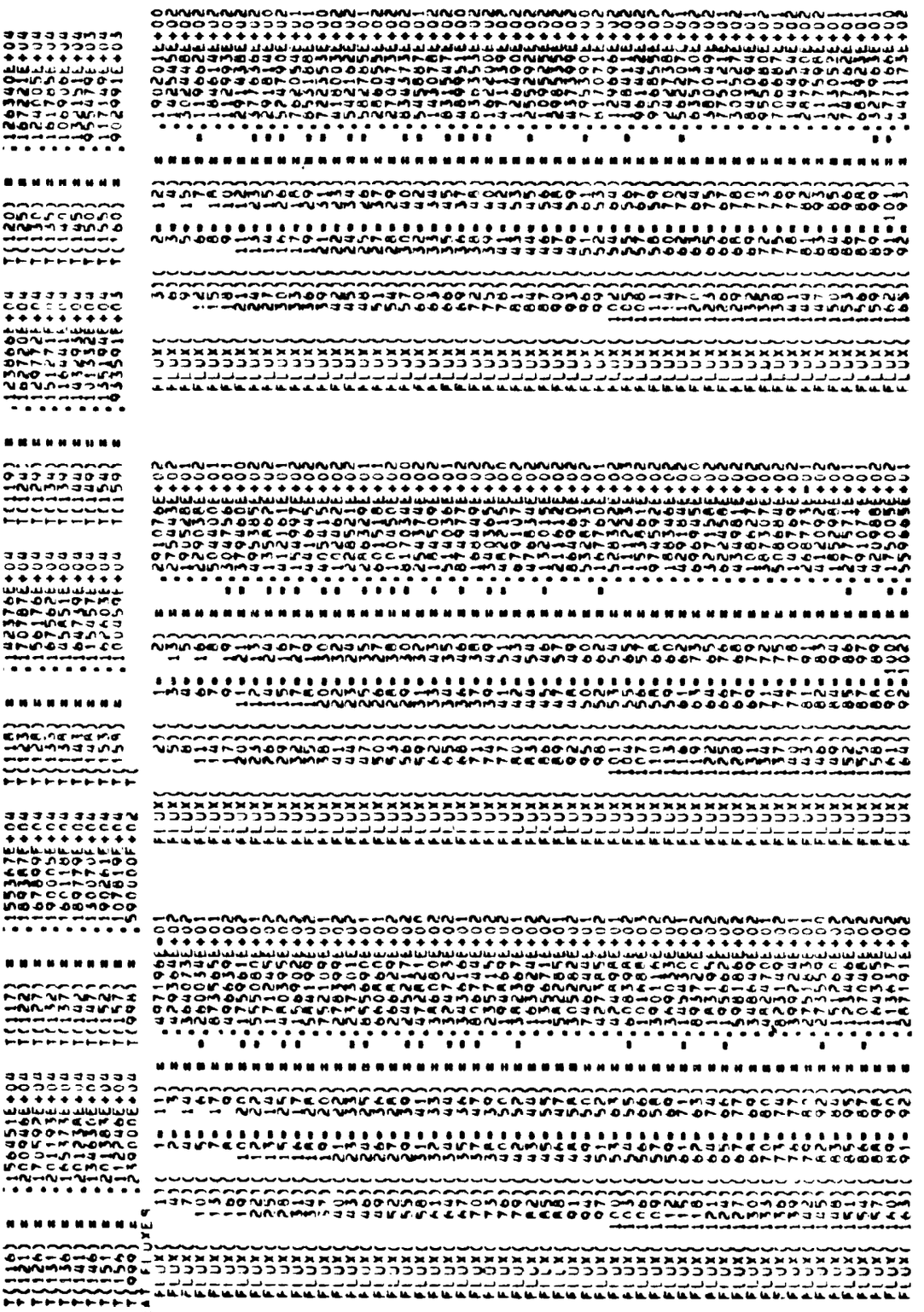


Figure 5-8. Model 2A Output (Sheet 17 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

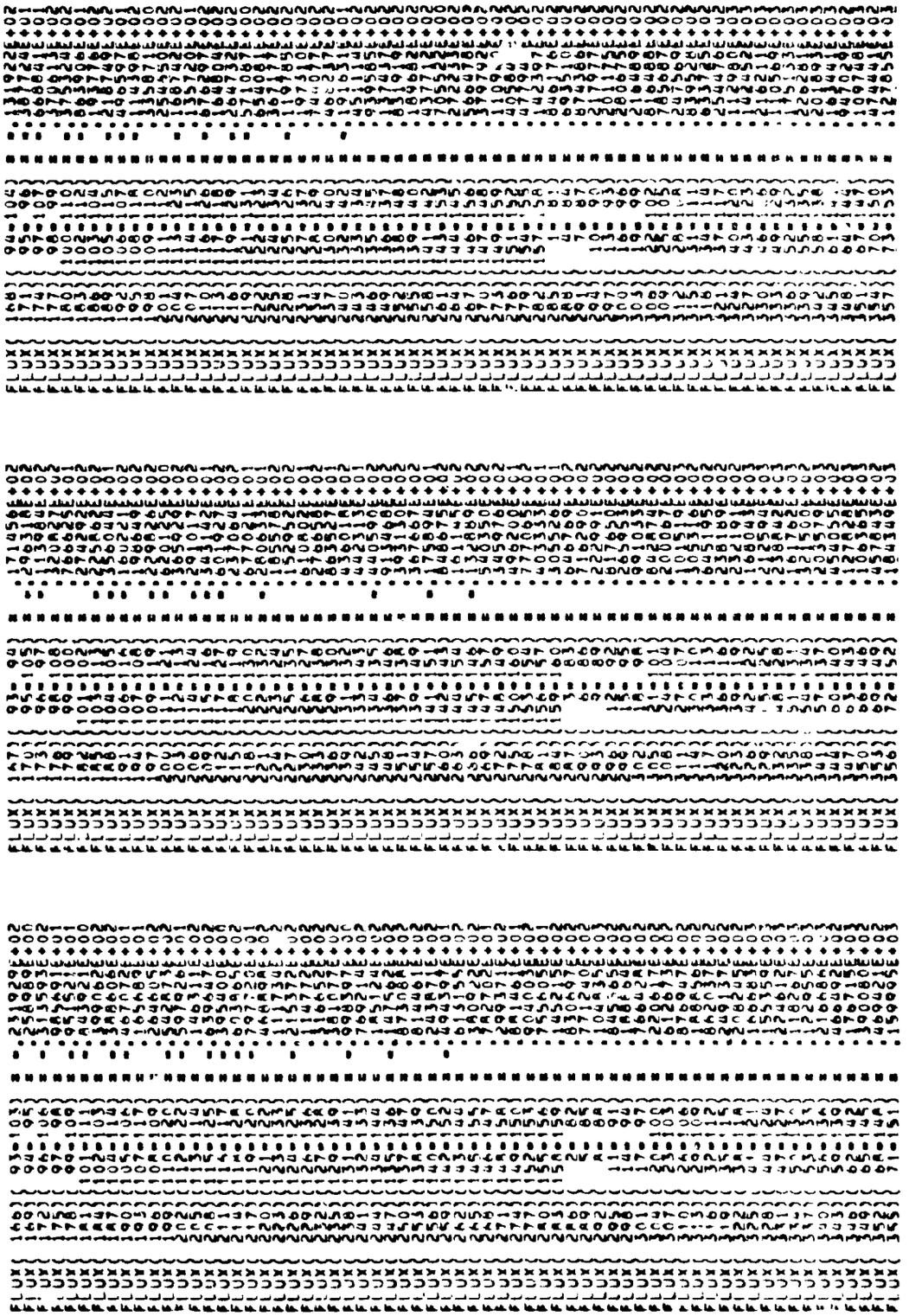


Figure 5-8. Model 2A Output (Sheet 18 of 49)

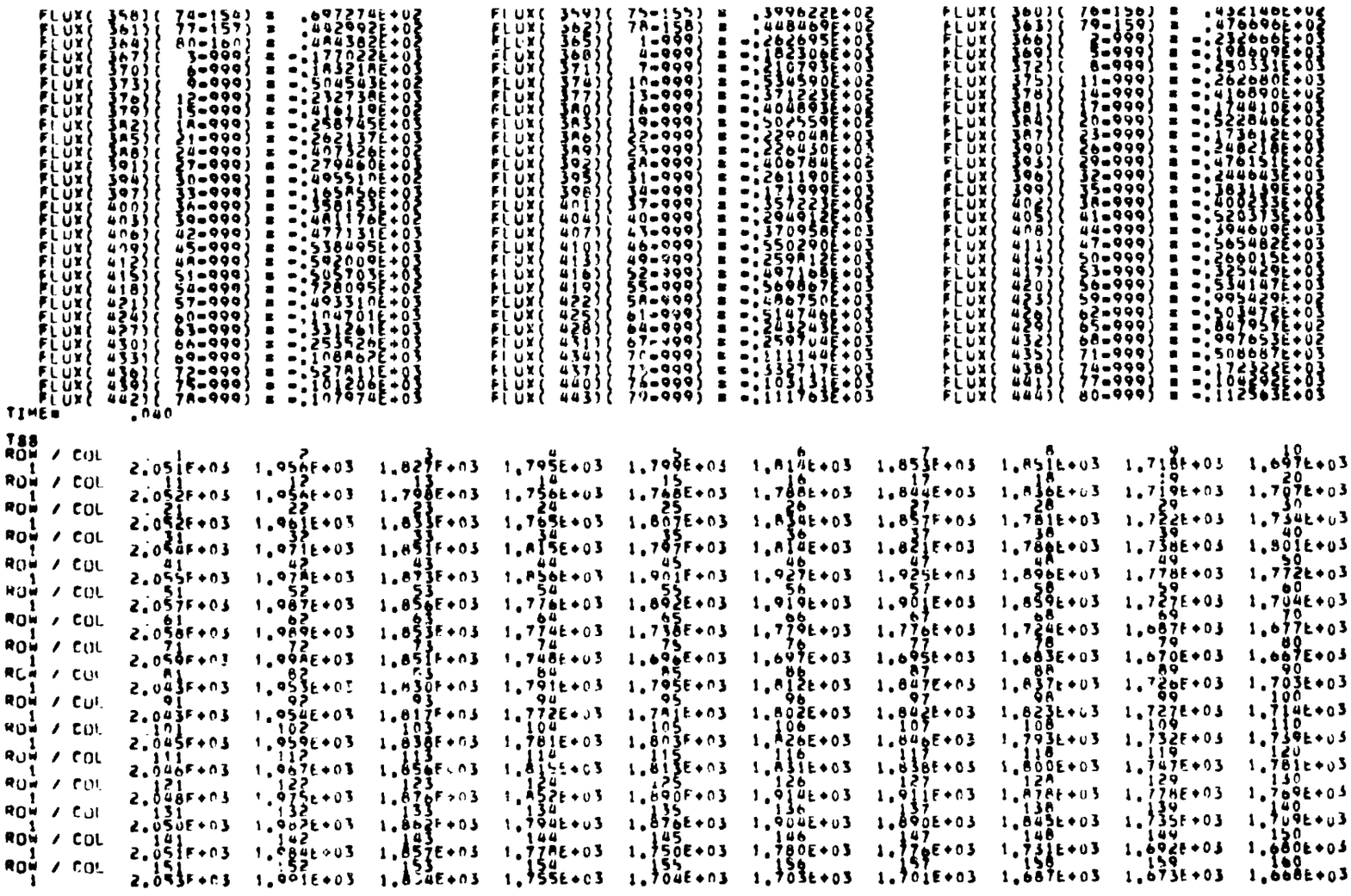


Figure 5-8. Model 2A Output (Sheet 19 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
ITERATION NUMBER =  5  MAXIMUM ABSOLUTE ERROR =     .667

EST ABS ERR
ROW / COL          1           2           3           4           5           6           7           8           9          10
        1  1.148E-05  8.802E-05  8.270E-04  1.493E-03  4.594E-03  8.424E-03  1.130E-02  4.822E-02  4.851E-02  7.458E-02
ROW / COL         11          12          13          14
        1  7.387E-02  1.185E-01  6.671E-01  9.505E-01

RAYLEIGH QUOTIENTS
ROW / COL          1           2           3           4           5           6           7           8           9          10
        1 -2.320E+01 -3.745E+01 -4.324E+01 -5.698E+01 -6.906E+01 -8.120E+01 -8.445E+01 -9.763E+01 -1.095E+02 -1.116E+02
ROW / COL         11          12          13          14
        1 -1.259E+02 -1.331E+02 -1.386E+02 -1.407E+02

DOMINANT EIGENVALUES
ROW / COL          1           2           3           4           5           6           7           8           9          10
        1 -2.320E+01 -3.745E+01 -4.324E+01 -5.698E+01 -6.906E+01 -8.120E+01 -8.445E+01 -9.763E+01 -1.095E+02 -1.116E+02
ROW / COL         11          12          13          14
        1 -1.259E+02 -1.331E+02 -1.386E+02 -1.407E+02

TIME =   .400E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL          1           2           3           4           5           6           7           8           9          10
        1  2.031E+03  1.905E+03  1.706E+03  1.626E+03  1.614E+03  1.628E+03  1.667E+03  1.612E+03  1.312E+03  1.229E+03
ROW / COL         11          12          13          14          15          16          17          18          19          20
        1  2.032E+03  1.905E+03  1.672E+03  1.577E+03  1.574E+03  1.596E+03  1.656E+03  1.589E+03  1.318E+03  1.253E+03
ROW / COL         21          22          23          24          25          26          27          28          29          30
        1  2.033E+03  1.913E+03  1.719E+03  1.595E+03  1.634E+03  1.663E+03  1.676E+03  1.507E+03  1.330F+03  1.310E+03
ROW / COL         31          32          33          34          35          36          37          38          39          40
        1  2.036F+03  1.926E+03  1.747E+03  1.666E+03  1.620E+03  1.644E+03  1.651E+03  1.519E+03  1.362E+03  1.452E+03
ROW / COL         41          42          43          44          45          46          47          48          49          50
        1  2.038E+03  1.937E+03  1.780F+03  1.727E+03  1.775F+03  1.809E+03  1.779F+03  1.686E+03  1.424E+03  1.377E+03
ROW / COL         51          52          53          54          55          56          57          58          59          60
        1  2.040F+03  1.945E+03  1.740F+03  1.600E+03  1.735E+03  1.760E+03  1.707E+03  1.585E+03  1.285E+03  1.200E+03
ROW / COL         61          62          63          64          65          66          67          68          69          70
        1  2.040E+03  1.944E+03  1.727F+03  1.552E+03  1.692E+03  1.772E+03  1.726E+03  1.276E+03  1.145E+03  1.090E+03
ROW / COL         71          72          73          74          75          76          77          78          79          80
        1  2.041F+03  1.951E+03  1.710F+03  1.479E+03  1.516E+03  1.268E+03  1.218E+03  1.142E+03  1.068E+03  1.034E+03
ROW / COL         81          82          83          84          85          86          87          88          89          90
        1  2.018F+03  1.894E+03  1.699F+03  1.610E+03  1.596E+03  1.612E+03  1.644E+03  1.574E+03  1.510E+03  1.225E+03
ROW / COL         91          92          93          94          95          96          97          98          99         100
        1  2.019F+03  1.895E+03  1.685F+03  1.586E+03  1.580E+03  1.601E+03  1.638E+03  1.553E+03  1.516E+03  1.249E+03
ROW / COL        101         102         103         104         105         106         107         108         109         110
        1  2.021F+03  1.903E+03  1.715F+03  1.604E+03  1.616E+03  1.640E+03  1.666E+03  1.509E+03  1.331E+03  1.302E+03
ROW / COL        111         112         113         114         115         116         117         118         119         120
        1  2.023F+03  1.915E+03  1.743F+03  1.655E+03  1.657E+03  1.653E+03  1.638E+03  1.523E+03  1.381E+03  1.370E+03
ROW / COL        121         122         123         124         125         126         127         128         129         130
        1  2.027F+03  1.927E+03  1.773F+03  1.710E+03  1.707E+03  1.771E+03  1.744F+03  1.640E+03  1.407E+03  1.353E+03
ROW / COL        131         132         133         134         135         136         137         138         139         140
        1  2.029F+03  1.933E+03  1.745F+03  1.611E+03  1.699E+03  1.723E+03  1.672E+03  1.544E+03  1.282E+03  1.194E+03
ROW / COL        141         142         143         144         145         146         147         148         149         150
        1  2.029F+03  1.931E+03  1.720F+03  1.544E+03  1.446F+03  1.457E+03  1.408E+03  1.271E+03  1.138F+03  1.081E+03
ROW / COL        151         152         153         154         155         156         157         158         159         160
        1  2.030F+03  1.933E+03  1.702F+03  1.475E+03  1.318E+03  1.264E+03  1.213E+03  1.135E+03  1.059E+03  1.023E+03

 TIME =   .400000E-01
 T(  1) =  .203143E+04   T(  2) =  .190500E+04   T(  3) =  .170594E+04   T(  4) =  .162598E+04   T(  5) =  .161356E+04
 T(  6) =  .162780E+04   T(  7) =  .166707E+04   T(  8) =  .161231E+04   T(  9) =  .131243E+04   T( 10) =  .132901E+04
 T( 11) =  .203198E+04   T( 12) =  .190538E+04   T( 13) =  .167177E+04   T( 14) =  .157710E+04   T( 15) =  .157430E+04
 T( 16) =  .159572E+04   T( 17) =  .165900E+04   T( 18) =  .158913E+04   T( 19) =  .131784E+04   T( 20) =  .125331E+04
 T( 21) =  .203347E+04   T( 22) =  .191290E+04   T( 23) =  .171941E+04   T( 24) =  .159512E+04   T( 25) =  .163383E+04
 T( 26) =  .166313E+04   T( 27) =  .167646E+04   T( 28) =  .150711E+04   T( 29) =  .133029E+04   T( 30) =  .130997E+04
 T( 31) =  .203556E+04   T( 32) =  .192646E+04   T( 33) =  .174742E+04   T( 34) =  .166639E+04   T( 35) =  .162903E+04
```

Figure 5-8. Model 2A Output (Sheet 20 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
PAGE IS POOR

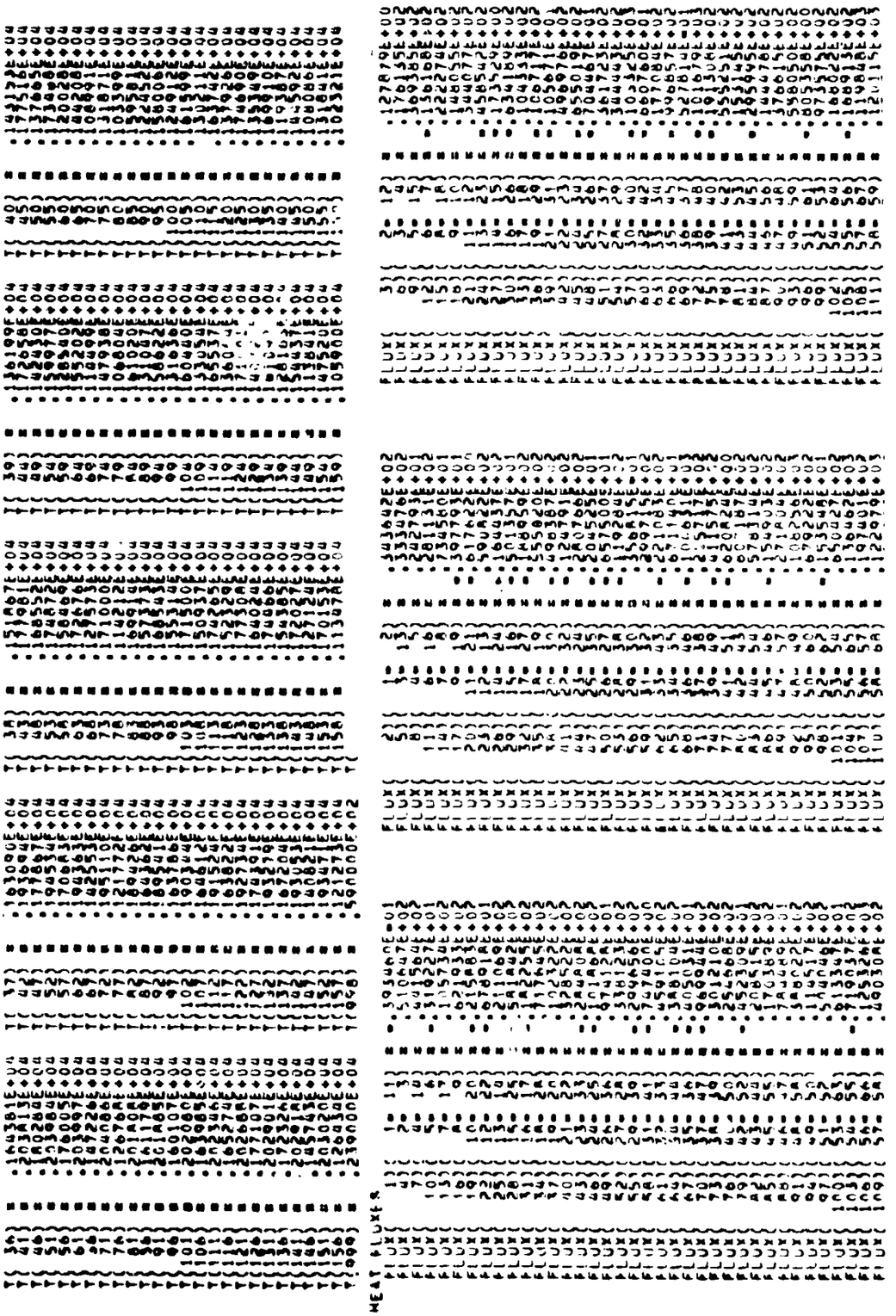


Figure 5-8. Model 2A Output (Sheet 21 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

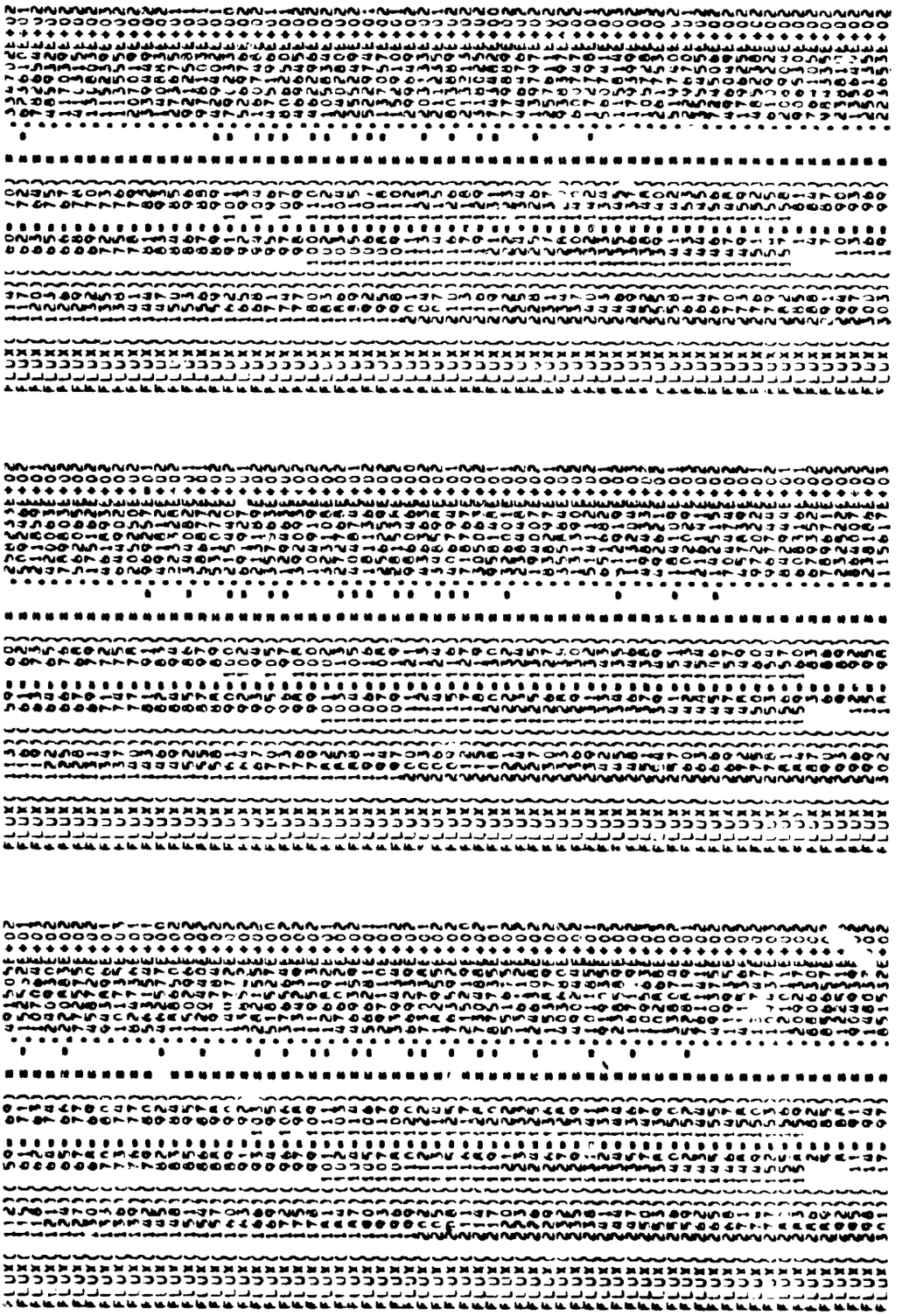


Figure 5-8. Model 2A Output (Sheet 22 of 49)

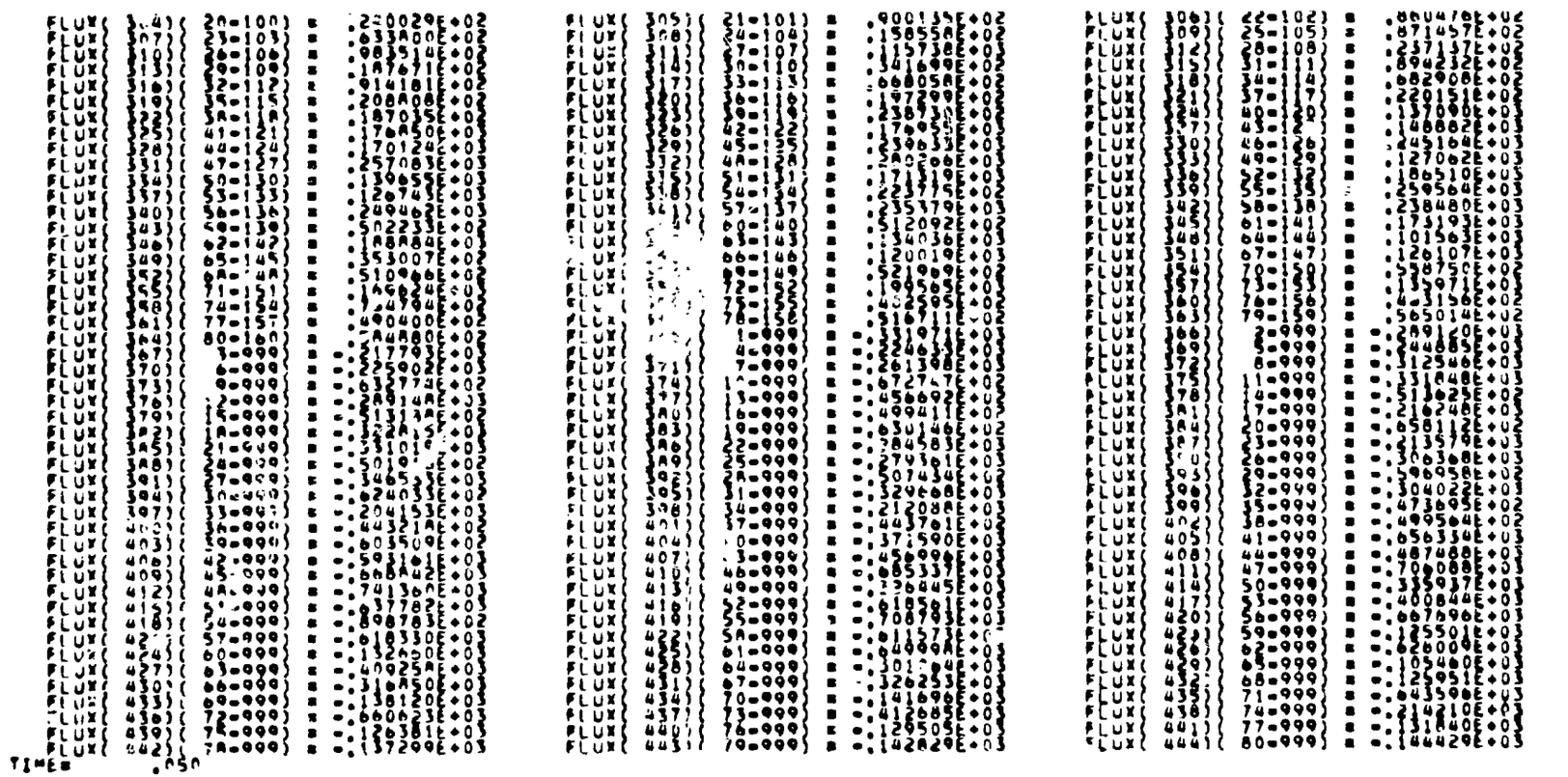


Figure 5-8. Model 2A Output (Sheet 23 of 49)

```
ROW / COL          81            82            83            84            85            86            87            88            89            90
  1          2.035E+03     1.938E+03     1.792E+03     1.741E+03     1.742E+03     1.760E+03     1.798E+03     1.780E+03     1.645E+03     1.614E+03
ROW / COL          91            92            93            94            95            96            97            98            99           100
  1          2.035E+03     1.936E+03     1.779E+03     1.720E+03     1.722E+03     1.750E+03     1.793E+03     1.765E+03     1.647E+03     1.627E+03
ROW / COL         101           102           103           104           105           106           107           108           109           110
  1          2.037E+03     1.942E+03     1.802E+03     1.737E+03     1.753E+03     1.778E+03     1.798E+03     1.732E+03     1.654E+03     1.657E+03
ROW / COL         111           112           113           114           115           116           117           118           119           120
  1          2.039E+03     1.951E+03     1.823E+03     1.771E+03     1.786E+03     1.795E+03     1.790E+03     1.741E+03     1.672E+03     1.706E+03
ROW / COL         121           122           123           124           125           126           127           128           129           130
  1          2.041E+03     1.960E+03     1.846E+03     1.813E+03     1.852E+03     1.878E+03     1.873E+03     1.828E+03     1.708E+03     1.693E+03
ROW / COL         131           132           133           134           135           136           137           138           139           140
  1          2.043E+03     1.967E+03     1.829E+03     1.747E+03     1.833E+03     1.863E+03     1.844E+03     1.788E+03     1.656E+03     1.623E+03
ROW / COL         141           142           143           144           145           146           147           148           149           150
  1          2.044E+03     1.969E+03     1.821E+03     1.723E+03     1.684E+03     1.715E+03     1.707E+03     1.652E+03     1.602E+03     1.586E+03
ROW / COL         151           152           153           154           155           156           157           158           159           160
  1          2.046E+03     1.976E+03     1.816E+03     1.692E+03     1.626E+03     1.621E+03     1.615E+03     1.596E+03     1.578E+03     1.571E+03

ITERATION NUMBER  3  MAXIMUM ABSOLUTE ERROR =     .458

EST ABS ERR
ROW / COL           1             2             3             4             5             6             7             8             9            10
  1          5.745E-06     7.265E-05     1.906E-04     7.434E-04     2.393E-03     3.866E-03     5.789E-03     3.263E-02     3.268E-02     4.812E-02
ROW / COL          11            12            13            14
  1          6.349E-02     9.862E-02     4.581E-01     2.489E-01

RAYLEIGH QUOTIENTS
ROW / COL           1             2             3             4             5             6             7             8             9            10
  1         -2.420E+01    -3.456E+01    -4.433E+01    -5.805E+01    -6.997E+01    -8.204E+01    -8.530E+01    -9.840E+01    -1.103E+02    -1.124E+02
ROW / COL          11            12            13            14
  1         -1.265E+02    -1.337E+02    -1.392E+02    -1.412E+02

DOMINANT EIGENVALUES
ROW / COL           1             2             3             4             5             6             7             8             9            10
  1         -2.420E+01    -3.456E+01    -4.432E+01    -5.805E+01    -6.997E+01    -8.204E+01    -8.530E+01    -9.840E+01    -1.103E+02    -1.124E+02
ROW / COL          11            12            13            14
  1         -1.265E+02    -1.337E+02    -1.392E+02    -1.412E+02

TIME =    .500E-01   NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL           1             2             3             4             5             6             7             8             9            10
  1          2.036E+03     1.917E+03     1.736E+03     1.669E+03     1.660E+03     1.671E+03     1.706E+03     1.659E+03     1.393E+03     1.321E+03
ROW / COL          11            12            13            14            15            16            17            18            19            20
  1          2.036E+03     1.917E+03     1.704E+03     1.623E+03     1.622E+03     1.640E+03     1.695E+03     1.638E+03     1.396E+03     1.341E+03
ROW / COL          21            22            23            24            25            26            27            28            29            30
  1          2.038E+03     1.924E+03     1.748E+03     1.678E+03     1.676E+03     1.702E+03     1.713E+03     1.560E+03     1.406E+03     1.390E+03
ROW / COL          31            32            33            34            35            36            37            38            39            40
  1          2.039E+03     1.937E+03     1.773E+03     1.703E+03     1.669E+03     1.681E+03     1.669E+03     1.569E+03     1.433E+03     1.499E+03
ROW / COL          41            42            43            44            45            46            47            48            49            50
  1          2.042E+03     1.946E+03     1.802E+03     1.757E+03     1.803E+03     1.828E+03     1.806E+03     1.723E+03     1.487E+03     1.446E+03
ROW / COL          51            52            53            54            55            56            57            58            59            60
  1          2.043E+03     1.954E+03     1.775E+03     1.640E+03     1.768E+03     1.790E+03     1.741E+03     1.631E+03     1.360E+03     1.284E+03
ROW / COL          61            62            63            64            65            66            67            68            69            70
  1          2.043E+03     1.953E+03     1.754E+03     1.602E+03     1.506E+03     1.533E+03     1.488E+03     1.351E+03     1.253E+03     1.183E+03
ROW / COL          71            72            73            74            75            76            77            78            79            80
  1          2.044E+03     1.961E+03     1.741E+03     1.540E+03     1.401E+03     1.355E+03     1.306E+03     1.214E+03     1.163E+03     1.130E+03
ROW / COL          81            82            83            84            85            86            87            88            89            90
  1          2.025E+03     1.910E+03     1.735E+03     1.661E+03     1.648E+03     1.662E+03     1.690E+03     1.629E+03     1.396E+03     1.321E+03
ROW / COL          91            92            93            94            95            96            97            98            99           100
  1          2.025E+03     1.911E+03     1.722E+03     1.637E+03     1.634E+03     1.651E+03     1.684E+03     1.609E+03     1.400E+03     1.342E+03
ROW / COL         101           102           103           104           105           106           107           108           109           110
  1          2.027E+03     1.918E+03     1.749E+03     1.653E+03     1.665E+03     1.685E+03     1.690E+03     1.568E+03     1.411E+03     1.388E+03
ROW / COL         111           112           113           114           115           116           117           118           119           120
  1          2.029E+03     1.929E+03     1.773E+03     1.698E+03     1.683E+03     1.695E+03     1.681E+03     1.579E+03     1.436E+03     1.456E+03
```

Figure 5-8. Model 2A Output (Sheet 24 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

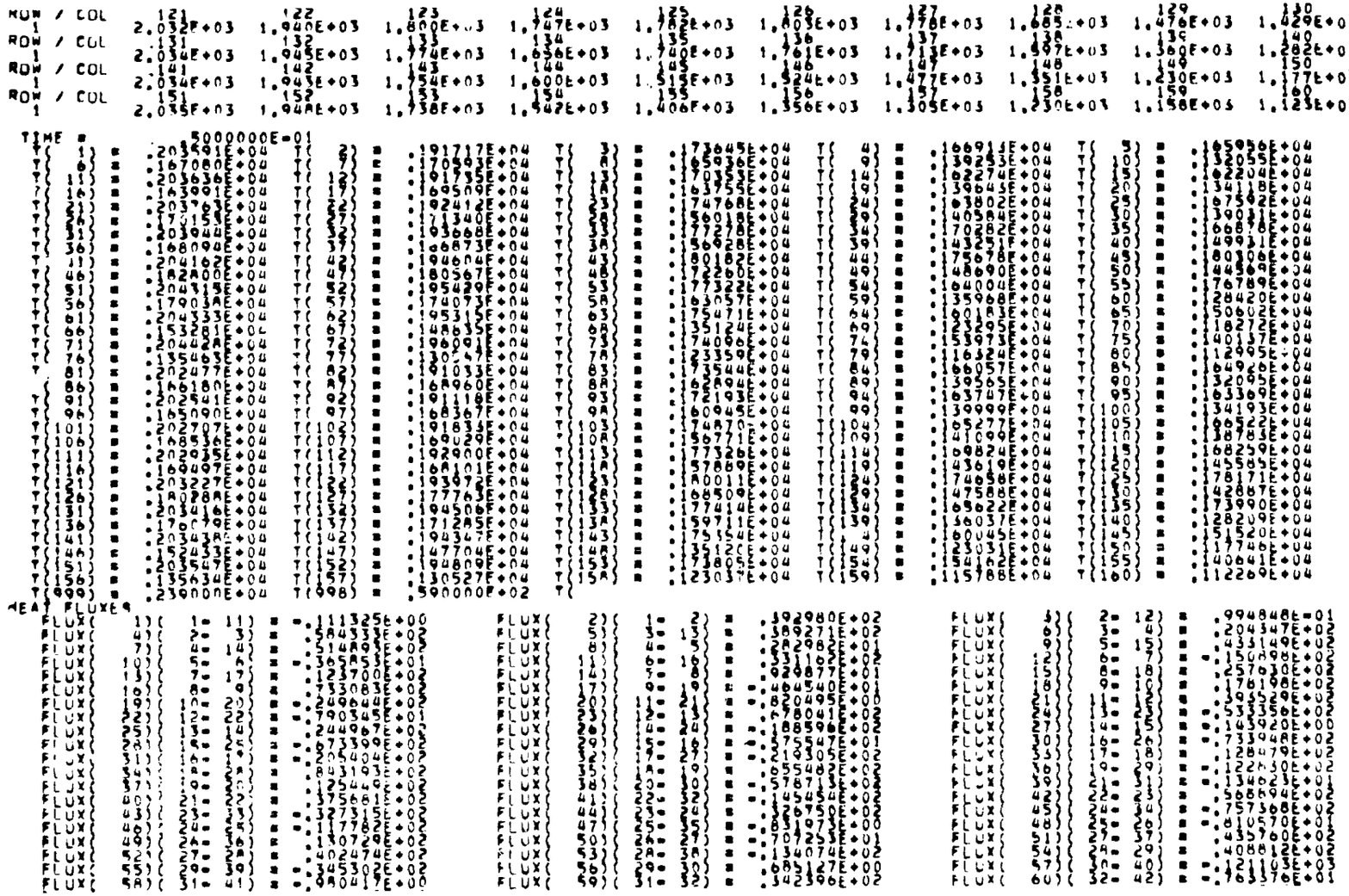


Figure 5-8. Model 2A Output (Sheet 25 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

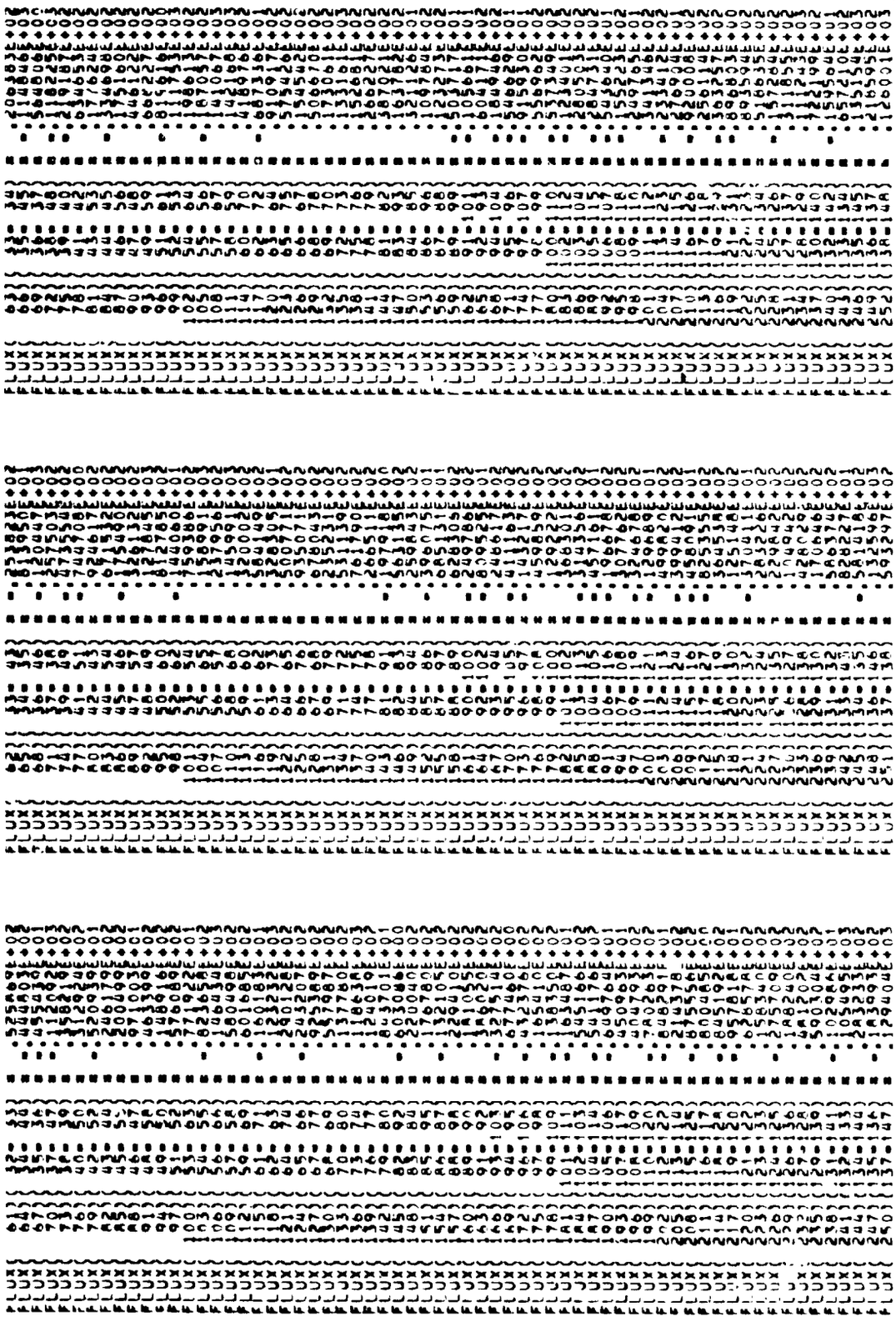


Figure 5-8. Model 2A Output (Sheet 26 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

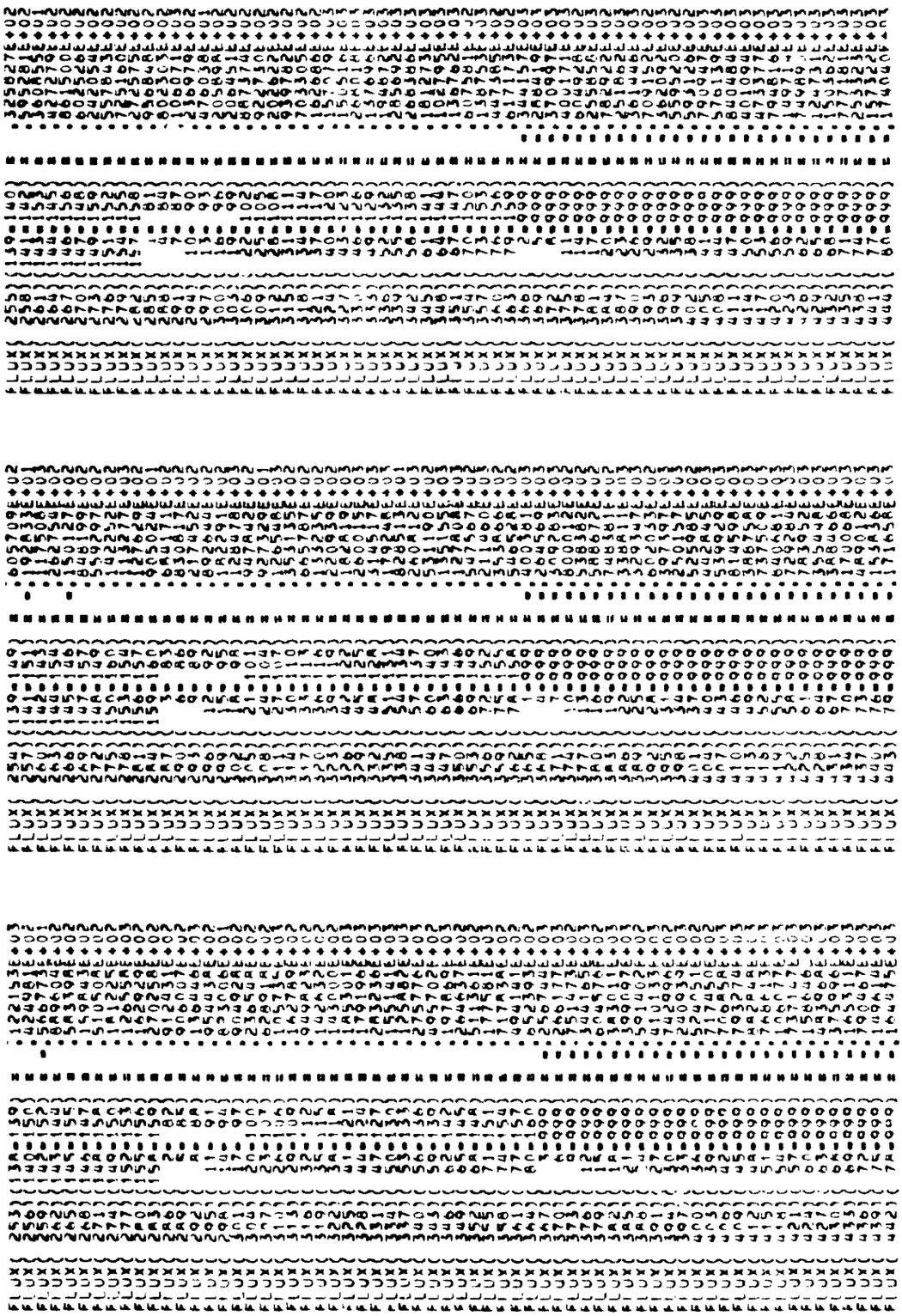


Figure 5-8. Model 2A Output (Sheet 27 of 49)

```
TIME=       .060

TSS
ROW / COL        1           2           3           4           5           6           7           8           9          10
     1  2.041E+03   1.931E+03   1.773E+03   1.721E+03   1.720E+03   1.736E+03   1.778E+03   1.764E+03   1.584E+03   1.548E+03
ROW / COL       11          12          13          14          15          16          17          18          19          20
     1  2.041E+03   1.931E+03   1.740E+03   1.678E+03   1.685E+03   1.708E+03   1.769E+03   1.746E+03   1.586E+03   1.562E+03
ROW / COL       21          22          23          24          25          26          27          28          29          30
     1  2.043E+03   1.937E+03   1.781E+03   1.691E+03   1.733E+03   1.702E+03   1.785E+03   1.682E+03   1.592E+03   1.598E+03
ROW / COL       31          32          33          34          35          36          37          38          39          40
     1  2.044E+03   1.949E+03   1.804E+03   1.749E+03   1.725E+03   1.743E+03   1.746E+03   1.689E+03   1.613E+03   1.682E+03
ROW / COL       41          42          43          44          45          46          47          48          49          50
     1  2.046E+03   1.955E+03   1.830E+03   1.799E+03   1.847E+03   1.875E+03   1.868E+03   1.821E+03   1.662E+03   1.647E+03
ROW / COL       51          52          53          54          55          56          57          58          59          60
     1  2.048E+03   1.967E+03   1.809E+03   1.703E+03   1.829E+03   1.858E+03   1.832E+03   1.769E+03   1.593E+03   1.556E+03
ROW / COL       61          62          63          64          65          66          67          68          69          70
     1  2.049E+03   1.968E+03   1.799E+03   1.688E+03   1.831E+03   1.674E+03   1.662E+03   1.589E+03   1.533E+03   1.515E+03
ROW / COL       71          72          73          74          75          76          77          78          79          80
     1  2.050E+03   1.977E+03   1.793E+03   1.649E+03   1.567E+03   1.559E+03   1.550E+03   1.528E+03   1.505E+03   1.497E+03
ROW / COL       81          82          83          84          85          86          87          88          89          90
     1  2.032E+03   1.927E+03   1.775E+03   1.719E+03   1.716E+03   1.734E+03   1.771E+03   1.747E+03   1.594E+03   1.557E+03
ROW / COL       91          92          93          94          95          96          97          98          99         100
     1  2.032E+03   1.928E+03   1.762E+03   1.697E+03   1.702E+03   1.724E+03   1.766E+03   1.731E+03   1.597E+03   1.571E+03
ROW / COL      101         102         103         104         105         106         107         108         109         110
     1  2.034E+03   1.934E+03   1.786E+03   1.710E+03   1.729E+03   1.754E+03   1.772E+03   1.696E+03   1.604E+03   1.604E+03
ROW / COL      111         112         113         114         115         116         117         118         119         120
     1  2.036E+03   1.944E+03   1.808E+03   1.750E+03   1.743E+03   1.761E+03   1.764E+03   1.706E+03   1.625E+03   1.657E+03
ROW / COL      121         122         123         124         125         126         127         128         129         130
     1  2.038E+03   1.954E+03   1.833E+03   1.794E+03   1.833E+03   1.859E+03   1.851E+03   1.798E+03   1.662E+03   1.643E+03
ROW / COL      131         132         133         134         135         136         137         138         139         140
     1  2.040E+03   1.961E+03   1.814E+03   1.723E+03   1.811E+03   1.840E+03   1.817E+03   1.751E+03   1.602E+03   1.563E+03
ROW / COL      141         142         143         144         145         146         147         148         149         150
     1  2.041E+03   1.962E+03   1.804E+03   1.693E+03   1.646E+03   1.675E+03   1.662E+03   1.598E+03   1.539E+03   1.519E+03
ROW / COL      151         152         153         154         155         156         157         158         159         160
     1  2.043E+03   1.966E+03   1.796E+03   1.654E+03   1.579E+03   1.606E+03   1.558E+03   1.533E+03   1.509E+03   1.500E+03

ITERATION NUMBER  2  MAXIMUM ABSOLUTE ERROR =     .369

EST ABS ERR
ROW / COL        1           2           3           4           5           6           7           8           9          10
     1  4.606E-04   1.372E-03   2.752E-03   4.921E-03   7.075E-03   1.147E-02   1.414E-02   4.815E-02   4.540E-02   5.336E-02
ROW / COL       11          12          13          14
     1  1.226E-01   1.170E-01   3.686E-01   2.416E-01

RAYLEIGH QUOTIENTS
ROW / COL        1           2           3           4           5           6           7           8           9          10
     1 -2.499E+01  -3.955E+01  -4.503E+01  -5.860E+01  -7.057E+01  -8.264E+01  -8.580E+01  -9.888E+01  -1.107E+02  -1.128E+02
ROW / COL       11          12          13          14
     1 -1.269E+02  -1.341E+02  -1.396E+02  -1.416E+02

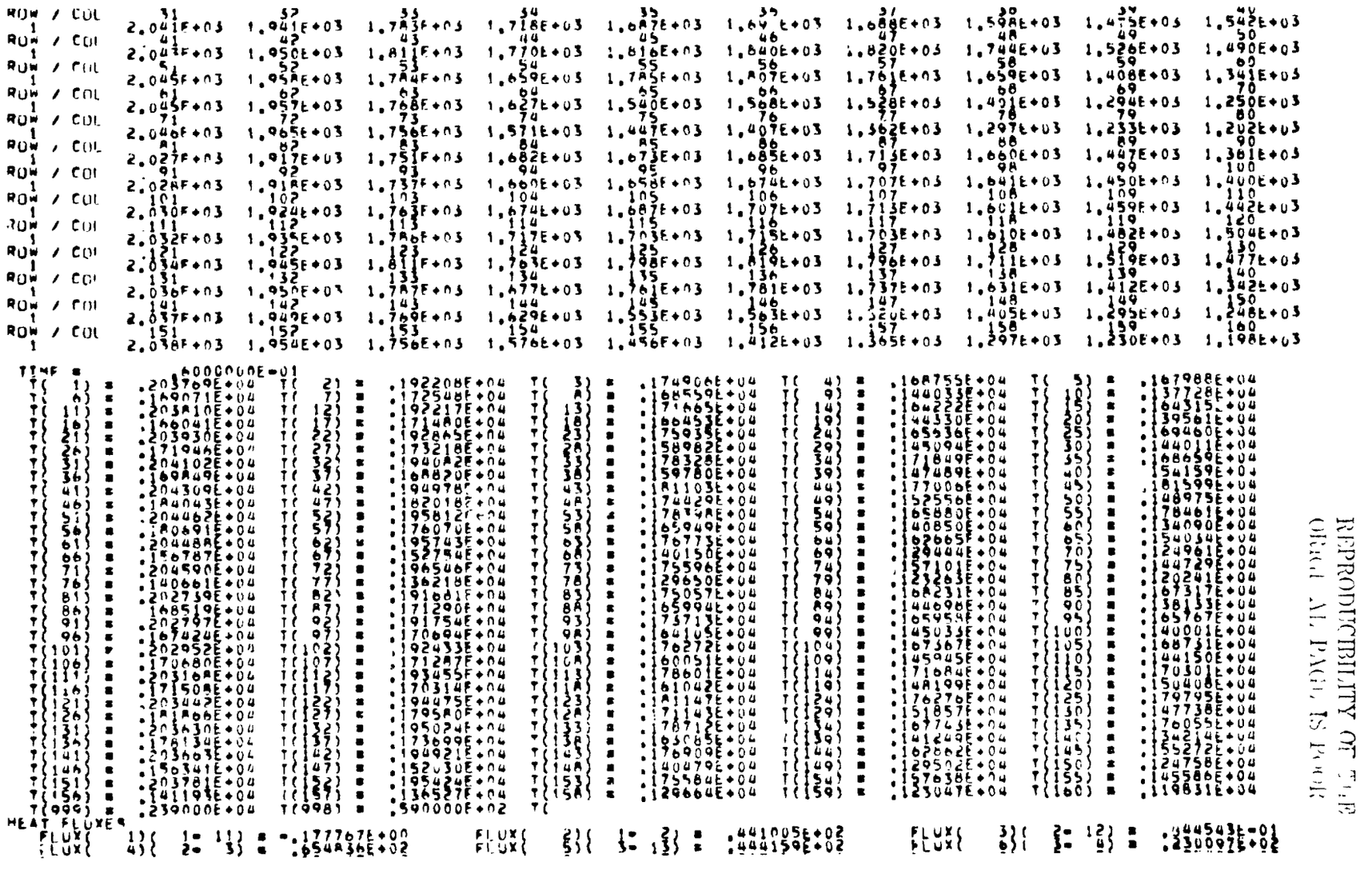
DOMINANT EIGENVALUES
ROW / COL        1           2           3           4           5           6           7           8           9          10
     1 -2.499E+01  -3.935E+01  -4.503E+01  -5.860E+01  -7.057E+01  -8.264E+01  -8.580E+01  -9.888E+01  -1.107E+02  -1.128E+02
ROW / COL       11          12          13          14
     1 -1.269E+02  -1.341E+02  -1.396E+02  -1.416E+02

TIME =   .600E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL        1           2           3           4           5           6           7           8           9          10
     1  2.038E+03   1.922E+03   1.740E+03   1.688E+03   1.680E+03   1.691E+03   1.725E+03   1.686E+03   1.440E+03   1.377E+03
ROW / COL       11          12          13          14          15          16          17          18          19          20
     1  2.038E+03   1.922E+03   1.717E+03   1.642E+03   1.643E+03   1.660E+03   1.715E+03   1.665E+03   1.443E+03   1.396E+03
ROW / COL       21          22          23          24          25          26          27          28          29          30
     1  2.039E+03   1.929E+03   1.759E+03   1.656E+03   1.695E+03   1.719E+03   1.732E+03   1.590E+03   1.451E+03   1.440E+03
```

Figure 5-8. Model 2A Output (Sheet 28 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



```
ROW / COL      31          32          33          34          35          36          37          38          39          40
     1    2.041E+03   1.941E+03   1.783E+03   1.718E+03   1.687E+03   1.647E+03   1.688E+03   1.598E+03   1.475E+03   1.342E+03
ROW / COL      41          42          43          44          45          46          47          48          49          50
     1    2.043E+03   1.950E+03   1.811E+03   1.770E+03   1.816E+03   1.840E+03   1.820E+03   1.744E+03   1.526E+03   1.490E+03
ROW / COL      51          52          53          54          55          56          57          58          59          60
     1    2.045E+03   1.958E+03   1.744E+03   1.659E+03   1.785E+03   1.807E+03   1.761E+03   1.659E+03   1.408E+03   1.341E+03
ROW / COL      61          62          63          64          65          66          67          68          69          70
     1    2.045E+03   1.957E+03   1.768E+03   1.627E+03   1.540E+03   1.568E+03   1.528E+03   1.401E+03   1.294E+03   1.250E+03
ROW / COL      71          72          73          74          75          76          77          78          79          80
     1    2.046E+03   1.965E+03   1.756E+03   1.571E+03   1.447E+03   1.407E+03   1.362E+03   1.297E+03   1.233E+03   1.202E+03
ROW / COL      81          82          83          84          85          86          87          88          89          90
     1    2.027E+03   1.917E+03   1.751E+03   1.682E+03   1.673E+03   1.685E+03   1.715E+03   1.660E+03   1.447E+03   1.381E+03
ROW / COL      91          92          93          94          95          96          97          98          99         100
     1    2.028E+03   1.918E+03   1.737E+03   1.660E+03   1.658E+03   1.674E+03   1.707E+03   1.641E+03   1.450E+03   1.400E+03
ROW / COL     101         102         103         104         105         106         107         108         109         110
     1    2.030E+03   1.924E+03   1.763E+03   1.674E+03   1.687E+03   1.707E+03   1.713E+03   1.601E+03   1.459E+03   1.442E+03
ROW / COL     111         112         113         114         115         116         117         118         119         120
     1    2.032E+03   1.935E+03   1.786E+03   1.717E+03   1.703E+03   1.715E+03   1.703E+03   1.610E+03   1.482E+03   1.504E+03
ROW / COL     121         122         123         124         125         126         127         128         129         130
     1    2.034E+03   1.945E+03   1.811E+03   1.763E+03   1.798E+03   1.819E+03   1.796E+03   1.711E+03   1.519E+03   1.477E+03
ROW / COL     131         132         133         134         135         136         137         138         139         140
     1    2.036E+03   1.950E+03   1.787E+03   1.677E+03   1.761E+03   1.781E+03   1.737E+03   1.631E+03   1.412E+03   1.342E+03
ROW / COL     141         142         143         144         145         146         147         148         149         150
     1    2.037E+03   1.949E+03   1.760E+03   1.629E+03   1.553E+03   1.563E+03   1.520E+03   1.405E+03   1.295E+03   1.248E+03
ROW / COL     151         152         153         154         155         156         157         158         159         160
     1    2.038E+03   1.954E+03   1.756E+03   1.576E+03   1.456E+03   1.412E+03   1.365E+03   1.297E+03   1.230E+03   1.198E+03

 TIME =  .6000000E-01
 T(  1) =  .2037695E+04   T( 21) =  .1922208E+04   T(  3) =  .1749066E+04   T(  4) =  .1687555E+04   T(  5) =  .1679885E+04
 T(  6) =  .1690715E+04   T(  7) =  .1725488E+04   T(  8) =  .1685596E+04   T(  9) =  .1440335E+04   T( 10) =  .1377228E+04
 T( 11) =  .2038510E+04   T( 12) =  .1922217E+04   T( 13) =  .1716655E+04   T( 14) =  .1644222E+04   T( 15) =  .1643151E+04
 T( 16) =  .1660041E+04   T( 17) =  .1714808E+04   T( 18) =  .1664533E+04   T( 19) =  .1443330E+04   T( 20) =  .1395611E+04
 T( 21) =  .2039308E+04   T( 22) =  .1928655E+04   T( 23) =  .1759335E+04   T( 24) =  .1655336E+04   T( 25) =  .1694605E+04
 T( 26) =  .1719446E+04   T( 27) =  .1732108E+04   T( 28) =  .1589822E+04   T( 29) =  .1450946E+04   T( 30) =  .1440011E+04
 T( 31) =  .2041026E+04   T( 32) =  .1940828E+04   T( 33) =  .1783288E+04   T( 34) =  .1718449E+04   T( 35) =  .1686596E+04
 T( 36) =  .1698496E+04   T( 37) =  .1748820E+04   T( 38) =  .1597806E+04   T( 39) =  .1474889E+04   T( 40) =  .1541596E+04
 T( 41) =  .2043096E+04   T( 42) =  .1949788E+04   T( 43) =  .1811036E+04   T( 44) =  .1770066E+04   T( 45) =  .1815996E+04
 T( 46) =  .1840436E+04   T( 47) =  .1820182E+04   T( 48) =  .1744229E+04   T( 49) =  .1525568E+04   T( 50) =  .1488975E+04
 T( 51) =  .2044626E+04   T( 52) =  .1958122E+04   T( 53) =  .1787988E+04   T( 54) =  .1655880E+04   T( 55) =  .1784616E+04
 T( 56) =  .1808916E+04   T( 57) =  .1760706E+04   T( 58) =  .1659409E+04   T( 59) =  .1408506E+04   T( 60) =  .1340006E+04
 T( 61) =  .2044886E+04   T( 62) =  .1957435E+04   T( 63) =  .1767736E+04   T( 64) =  .1626657E+04   T( 65) =  .1340644E+04
 T( 66) =  .1567876E+04   T( 67) =  .1527546E+04   T( 68) =  .1401506E+04   T( 69) =  .1204446E+04   T( 70) =  .1249616E+04
 T( 71) =  .2045906E+04   T( 72) =  .1965466E+04   T( 73) =  .1755966E+04   T( 74) =  .1571016E+04   T( 75) =  .1447296E+04
 T( 76) =  .1406616E+04   T( 77) =  .1362186E+04   T( 78) =  .1296506E+04   T( 79) =  .1232636E+04   T( 80) =  .1202416E+04
 T( 81) =  .2027536E+04   T( 82) =  .1916616E+04   T( 83) =  .1750576E+04   T( 84) =  .1682316E+04   T( 85) =  .1673176E+04
 T( 86) =  .1685196E+04   T( 87) =  .1712906E+04   T( 88) =  .1659946E+04   T( 89) =  .1440696E+04   T( 90) =  .1381536E+04
 T( 91) =  .2027976E+04   T( 92) =  .1917546E+04   T( 93) =  .1737136E+04   T( 94) =  .1659596E+04   T( 95) =  .1657676E+04
 T( 96) =  .1674246E+04   T( 97) =  .1706046E+04   T( 98) =  .1641056E+04   T( 99) =  .1450336E+04   T(100) =  .1400016E+04
 T(101) =  .2029526E+04   T(102) =  .1924336E+04   T(103) =  .1762726E+04   T(104) =  .1673676E+04   T(105) =  .1687316E+04
 T(106) =  .1706806E+04   T(107) =  .1712076E+04   T(108) =  .1610056E+04   T(109) =  .1459456E+04   T(110) =  .1441506E+04
 T(111) =  .2031686E+04   T(112) =  .1934556E+04   T(113) =  .1786016E+04   T(114) =  .1716846E+04   T(115) =  .1703016E+04
 T(116) =  .1715086E+04   T(117) =  .1703146E+04   T(118) =  .1611046E+04   T(119) =  .1481996E+04   T(120) =  .1504086E+04
 T(121) =  .2034426E+04   T(122) =  .1944756E+04   T(123) =  .1811476E+04   T(124) =  .1762766E+04   T(125) =  .1797956E+04
 T(126) =  .1818666E+04   T(127) =  .1795806E+04   T(128) =  .1711436E+04   T(129) =  .1518576E+04   T(130) =  .1477386E+04
 T(131) =  .2036306E+04   T(132) =  .1950246E+04   T(133) =  .1787126E+04   T(134) =  .1677656E+04   T(135) =  .1760556E+04
 T(136) =  .1761346E+04   T(137) =  .1736996E+04   T(138) =  .1650856E+04   T(139) =  .1412496E+04   T(140) =  .1342726E+04
 T(141) =  .2036036E+04   T(142) =  .1949216E+04   T(143) =  .1769096E+04   T(144) =  .1678626E+04   T(145) =  .1552726E+04
 T(146) =  .1503416E+04   T(147) =  .1523036E+04   T(148) =  .1400796E+04   T(149) =  .1295026E+04   T(150) =  .1247586E+04
 T(151) =  .2037816E+04   T(152) =  .1954246E+04   T(153) =  .1755846E+04   T(154) =  .1576386E+04   T(155) =  .1455866E+04
 T(156) =  .1411936E+04   T(157) =  .1365276E+04   T(158) =  .1296646E+04   T(159) =  .1230476E+04   T(160) =  .1198316E+04
 T(999) =  .2390006E+04   T(9981) =  .5900006E+02   T(

HEAT FLUXES
   FLUX(  1)(  1= 11) =  -.1777676E+00      FLUX(  2)(  1=  2) =  .4411005E+02      FLUX(  3)(  2= 12) =  .3445436E-01
   FLUX(  4)(  2=  3) =  .6548366E+02      FLUX(  5)(  3= 13) =  .4441596E+02      FLUX(  6)(  3=  4) =  .2300926E+02
```

Figure 5-8. Model 2A Output (Sheet 29 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

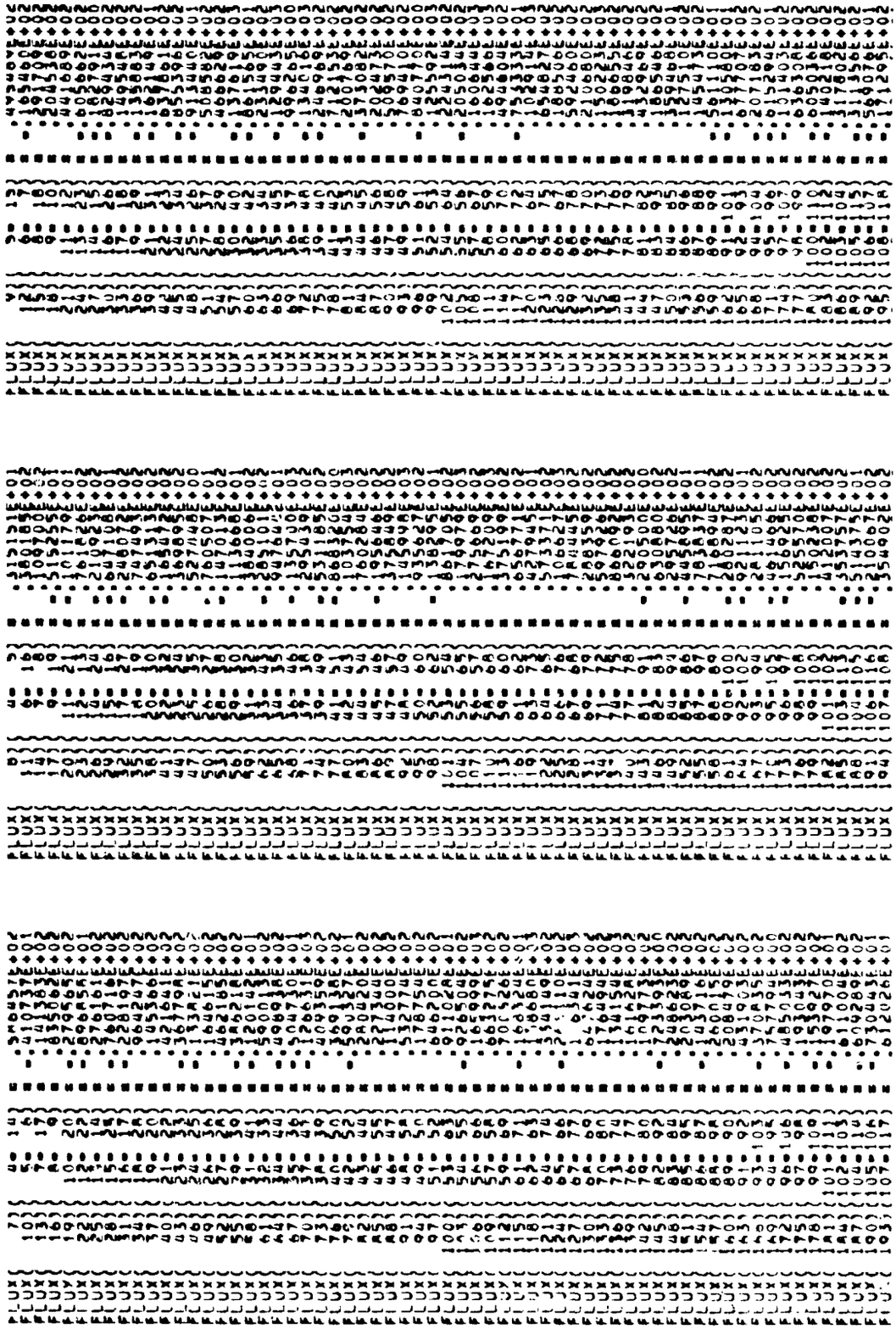


Figure 5-8. Model 2A Output (Sheet 30 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

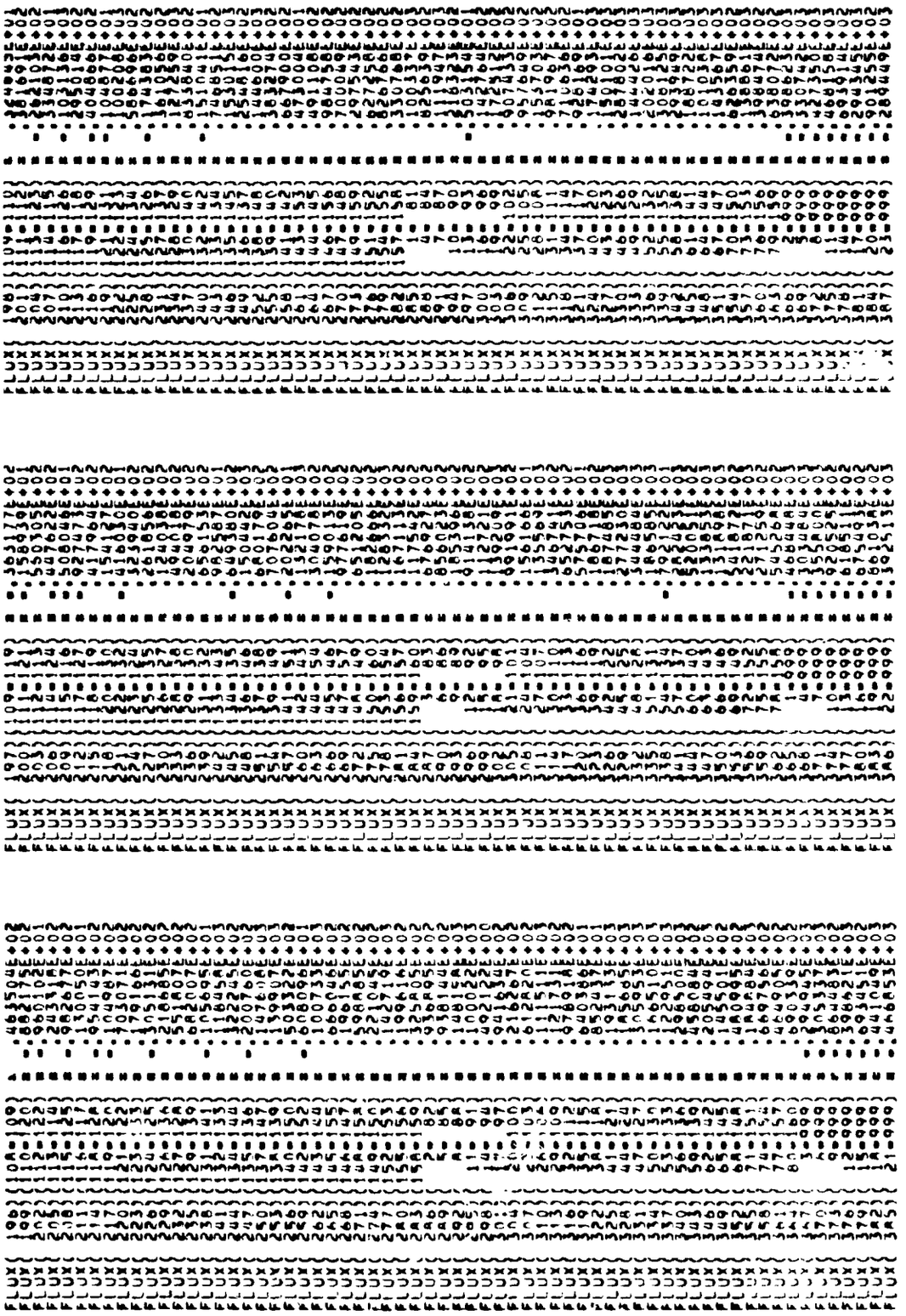
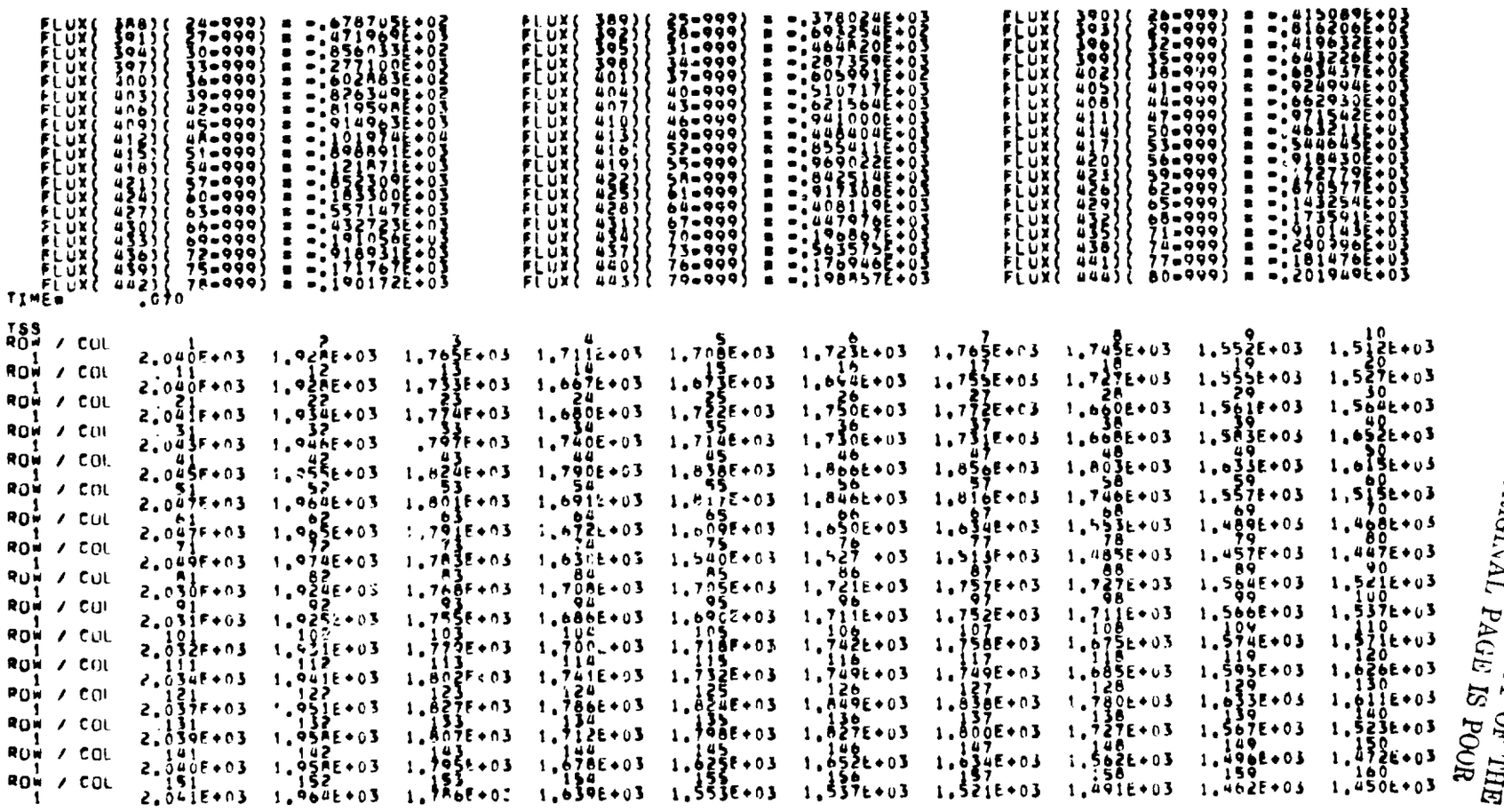


Figure 5-8. Model 2A Output (Sheet 31 of 49)



```
 FLUX( 388)( 24-999) =  .678705E+02     FLUX( 389)( 25-999) =  .378024E+03     FLUX( 390)( 26-999) =  .415089E+03
 FLUX( 391)( 27-999) =  .471964E+03     FLUX( 392)( 28-999) =  .693254E+03     FLUX( 393)( 29-999) =  .816206E+03
 FLUX( 394)( 30-999) =  .856033E+02     FLUX( 395)( 31-999) =  .464820E+03     FLUX( 396)( 32-999) =  .419632E+03
 FLUX( 397)( 33-999) =  .277100E+03     FLUX( 398)( 34-999) =  .287359E+03     FLUX( 399)( 35-999) =  .643226E+03
 FLUX( 400)( 36-999) =  .602A83E+02     FLUX( 401)( 37-999) =  .805961E+03     FLUX( 402)( 38-999) =  .683437E+03
 FLUX( 403)( 39-999) =  .826349E+02     FLUX( 404)( 40-999) =  .510717E+03     FLUX( 405)( 41-999) =  .924994E+03
 FLUX( 406)( 42-999) =  .819598E+02     FLUX( 407)( 43-999) =  .621564E+03     FLUX( 408)( 44-999) =  .662930E+03
 FLUX( 409)( 45-999) =  .914963E+03     FLUX( 410)( 46-999) =  .941000E+03     FLUX( 411)( 47-999) =  .971542E+03
 FLUX( 412)( 48-999) =  .101974E+04     FLUX( 413)( 49-999) =  .448404E+03     FLUX( 414)( 50-999) =  .463211E+03
 FLUX( 415)( 51-999) =  .898891E+03     FLUX( 416)( 52-999) =  .855411E+03     FLUX( 417)( 53-999) =  .544645E+03
 FLUX( 418)( 54-999) =  .121A71E+03     FLUX( 419)( 55-999) =  .969022E+03     FLUX( 420)( 56-999) =  .918430E+03
 FLUX( 421)( 57-999) =  .852309E+03     FLUX( 422)( 58-999) =  .842514E+03     FLUX( 423)( 59-999) =  .772779E+03
 FLUX( 424)( 60-999) =  .183300E+03     FLUX( 425)( 61-999) =  .917308E+03     FLUX( 426)( 62-999) =  .670577E+03
 FLUX( 427)( 63-999) =  .557147E+03     FLUX( 428)( 64-999) =  .408119E+03     FLUX( 429)( 65-999) =  .143254E+03
 FLUX( 430)( 66-999) =  .432723E+03     FLUX( 431)( 67-999) =  .447976E+03     FLUX( 432)( 68-999) =  .173501E+03
 FLUX( 433)( 69-999) =  .191056E+03     FLUX( 434)( 70-999) =  .190867E+03     FLUX( 435)( 71-999) =  .910143E+03
 FLUX( 436)( 72-999) =  .918931E+03     FLUX( 437)( 73-999) =  .563575E+03     FLUX( 438)( 74-999) =  .240996E+03
 FLUX( 439)( 75-999) =  .171767E+03     FLUX( 440)( 76-999) =  .176946E+03     FLUX( 441)( 77-999) =  .181476E+03
 FLUX( 442)( 78-999) =  .190172E+03     FLUX( 443)( 79-999) =  .198857E+03     FLUX( 444)( 80-999) =  .201949E+03

TIME=      .070

TSS
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1        2.040E+03   1.928E+03   1.765E+03   1.711E+03   1.708E+03   1.723E+03   1.765E+03   1.745E+03   1.552E+03   1.512E+03
ROW / COL       11          12          13          14          15          16          17          18          19          20
    1        2.040E+03   1.928E+03   1.733E+03   1.667E+03   1.673E+03   1.644E+03   1.755E+03   1.727E+03   1.555E+03   1.527E+03
ROW / COL       21          22          23          24          25          26          27          28          29          30
    1        2.041E+03   1.934E+03   1.774E+03   1.680E+03   1.722E+03   1.750E+03   1.772E+03   1.660E+03   1.561E+03   1.564E+03
ROW / COL       31          32          33          34          35          36          37          38          39          40
    1        2.043E+03   1.944E+03   1.797E+03   1.740E+03   1.714E+03   1.730E+03   1.731E+03   1.668E+03   1.583E+03   1.652E+03
ROW / COL       41          42          43          44          45          46          47          48          49          50
    1        2.045E+03   1.956E+03   1.824E+03   1.790E+03   1.838E+03   1.866E+03   1.856E+03   1.803E+03   1.633E+03   1.615E+03
ROW / COL       51          52          53          54          55          56          57          58          59          60
    1        2.047E+03   1.964E+03   1.801E+03   1.691E+03   1.817E+03   1.846E+03   1.816E+03   1.746E+03   1.557E+03   1.515E+03
ROW / COL       61          62          63          64          65          66          67          68          69          70
    1        2.047E+03   1.965E+03   1.791E+03   1.672E+03   1.809E+03   1.850E+03   1.834E+03   1.553E+03   1.489E+03   1.468E+03
ROW / COL       71          72          73          74          75          76          77          78          79          80
    1        2.049E+03   1.974E+03   1.783E+03   1.638E+03   1.540E+03   1.527 +03   1.513E+03   1.485E+03   1.457E+03   1.447E+03
ROW / COL       81          82          83          84          85          86          87          88          89          90
    1        2.050E+03   1.924E+03   1.748E+03   1.708E+03   1.705E+03   1.721E+03   1.757E+03   1.727E+03   1.564E+03   1.521E+03
ROW / COL       91          92          93          94          95          96          97          98          99         100
    1        2.051E+03   1.925E+03   1.755E+03   1.686E+03   1.690E+03   1.711E+03   1.752E+03   1.711E+03   1.586E+03   1.537E+03
ROW / COL      101         102         103         104         105         106         107         108         109         110
    1        2.052E+03   1.931E+03   1.772E+03   1.700E+03   1.718E+03   1.742E+03   1.758E+03   1.675E+03   1.574E+03   1.571E+03
ROW / COL      111         112         113         114         115         116         117         118         119         120
    1        2.054E+03   1.941E+03   1.802E+03   1.741E+03   1.732E+03   1.749E+03   1.749E+03   1.685E+03   1.595E+03   1.626E+03
ROW / COL      121         122         123         124         125         126         127         128         129         130
    1        2.057E+03   1.951E+03   1.827E+03   1.786E+03   1.824E+03   1.849E+03   1.838E+03   1.780E+03   1.633E+03   1.611E+03
ROW / COL      131         132         133         134         135         136         137         138         139         140
    1        2.059E+03   1.958E+03   1.807E+03   1.712E+03   1.700E+03   1.827E+03   1.800E+03   1.727E+03   1.567E+03   1.523E+03
ROW / COL      141         142         143         144         145         146         147         148         149         150
    1        2.060E+03   1.958E+03   1.795E+03   1.678E+03   1.625E+03   1.652E+03   1.634E+03   1.562E+03   1.496E+03   1.472E+03
ROW / COL      151         152         153         154         155         156         157         158         159         160
    1        2.061E+03   1.964E+03   1.786E+03   1.639E+03   1.553E+03   1.537E+03   1.521E+03   1.491E+03   1.462E+03   1.450E+03

ITERATION NUMBER  2  MAXIMUM ABSOLU  ERROR =     .296

EST ABS ERR
ROW / COL        1           2           3           4           5           6           7           8           9          10
    1        3.634E-04   9.288E-04   2.106E-03   3.548E-03   5.024E-03   9.470E-03   1.134E-02   3.638E-02   3.747E-02   3.748E-02
ROW / COL       11          12          13          14
    1        1.470E-01   1.213E-01   2.964E-01   2.352E-01
```

Figure 5-8. Model 2A Output (Sheet 32 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
RAYLEIGH QUOTIENTS
ROW / COL        1              2              3              4              5              6              7              8              9             10
    1   -2.557E+01  -3.987E+01  -4.546E+01  -5.888E+01  -7.094E+01  -8.305E+01  -8.610E+01  -9.918E+01  -1.110E+02  -1.131E+02
ROW / COL       11             12             13             14
    1   -1.272E+02  -1.344E+02  -1.399E+02  -1.419E+02

DOMINANT EIGENVALUES
ROW / COL        1              2              3              4              5              6              7              8              9             10
    1   -2.557E+01  -3.987E+01  -4.546E+01  -5.888E+01  -7.094E+01  -8.305E+01  -8.610E+01  -9.918E+01  -1.110E+02  -1.131E+02
ROW / COL       11             12             13             14
    1   -1.272E+02  -1.344E+02  -1.399E+02  -1.419E+02

TIME =   .700E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL        1              2              3              4              5              6              7              8              9             10
    1    2.038E+03   1.924E+03   1.754E+03   1.695E+03   1.688E+03   1.700E+03   1.736E+03   1.700E+03   1.468E+03   1.411E+03
ROW / COL       11             12             13             14             15             16             17             18             19             20
    1    2.039E+03   1.924E+03   1.722E+03   1.651E+03   1.653E+03   1.670E+03   1.725E+03   1.680E+03   1.471E+03   1.428E+03
ROW / COL       21             22             23             24             25             26             27             28             29             30
    1    2.040E+03   1.931E+03   1.764E+03   1.694E+03   1.703E+03   1.728E+03   1.742E+03   1.607E+03   1.477E+03   1.470E+03
ROW / COL       31             32             33             34             35             36             37             38             39             40
    1    2.042E+03   1.943E+03   1.788E+03   1.725E+03   1.695E+03   1.707E+03   1.699E+03   1.614E+03   1.500E+03   1.567E+03
ROW / COL       41             42             43             44             45             46             47             48             49             50
    1    2.044E+03   1.951E+03   1.815E+03   1.776E+03   1.822E+03   1.847E+03   1.828E+03   1.757E+03   1.549E+03   1.517E+03
ROW / COL       51             52             53             54             55             56             57             58             59             60
    1    2.045E+03   1.960E+03   1.789E+03   1.668E+03   1.793E+03   1.816E+03   1.773E+03   1.678E+03   1.440E+03   1.378E+03
ROW / COL       61             62             63             64             65             66             67             68             69             70
    1    2.046E+03   1.959E+03   1.774E+03   1.630E+03   1.550E+03   1.588E+03   1.552E+03   1.434E+03   1.336E+03   1.296E+03
ROW / COL       71             72             73             74             75             76             77             78             79             80
    1    2.047E+03   1.966E+03   1.763E+03   1.587E+03   1.472E+03   1.437E+03   1.397E+03   1.338E+03   1.281E+03   1.254E+03
ROW / COL       81             82             83             84             85             86             87             88             89             90
    1    2.048E+03   1.919E+03   1.757E+03   1.692E+03   1.684E+03   1.696E+03   1.725E+03   1.677E+03   1.477E+03   1.417E+03
ROW / COL       91             92             93             94             95             96             97             98             99            100
    1    2.029E+03   1.920E+03   1.744E+03   1.669E+03   1.668E+03   1.685E+03   1.719E+03   1.659E+03   1.480E+03   1.435E+03
ROW / COL      101            102            103            104            105            106            107            108            109            110
    1    2.031E+03   1.927E+03   1.769E+03   1.683E+03   1.697E+03   1.717E+03   1.725E+03   1.619E+03   1.488E+03   1.474E+03
ROW / COL      111            112            113            114            115            116            117            118            119            120
    1    2.033E+03   1.937E+03   1.791E+03   1.725E+03   1.712E+03   1.725E+03   1.715E+03   1.628E+03   1.509E+03   1.534E+03
ROW / COL      121            122            123            124            125            126            127            128            129            130
    1    2.035E+03   1.947E+03   1.816E+03   1.770E+03   1.800E+03   1.827E+03   1.809E+03   1.767E+03   1.545E+03   1.508E+03
ROW / COL      131            132            133            134            135            136            137            138            139            140
    1    2.037E+03   1.953E+03   1.793E+03   1.688E+03   1.771E+03   1.793E+03   1.751E+03   1.652E+03   1.446E+03   1.382E+03
ROW / COL      141            142            143            144            145            146            147            148            149            150
    1    2.038E+03   1.952E+03   1.777E+03   1.643E+03   1.573E+03   1.586E+03   1.547E+03   1.440E+03   1.339E+03   1.296E+03
ROW / COL      151            152            153            154            155            156            157            158            159            160
    1    2.039E+03   1.957E+03   1.765E+03   1.595E+03   1.483E+03   1.444E+03   1.403E+03   1.341E+03   1.281E+03   1.252E+03

TIME =   .700000000E-01
T(  1) =  .203841E+04   T(  2) =  .192411E+04   T(  3) =  .175434E+04   T(  4) =  .169542E+04   T(  5) =  .166887E+04
T(  6) =  .170008E+04   T(  7) =  .173552E+04   T(  8) =  .170021E+04   T(  9) =  .146816E+04   T( 10) =  .141101E+04
T( 11) =  .203881E+04   T( 12) =  .192417E+04   T( 13) =  .172216E+04   T( 14) =  .165056E+04   T( 15) =  .165252E+04
T( 16) =  .167009E+04   T( 17) =  .172497E+04   T( 18) =  .167962E+04   T( 19) =  .147066E+04   T( 20) =  .142806E+04
T( 21) =  .203997E+04   T( 22) =  .193053E+04   T( 23) =  .176422E+04   T( 24) =  .166426E+04   T( 25) =  .170296E+04
T( 26) =  .172802E+04   T( 27) =  .174199E+04   T( 28) =  .160652E+04   T( 29) =  .147745E+04   T( 30) =  .147000E+04
T( 31) =  .204165E+04   T( 32) =  .194255E+04   T( 33) =  .178778E+04   T( 34) =  .172533E+04   T( 35) =  .169467E+04
T( 36) =  .170702E+04   T( 37) =  .169854E+04   T( 38) =  .161408E+04   T( 39) =  .150011E+04   T( 40) =  .156710E+04
T( 41) =  .204368E+04   T( 42) =  .195137E+04   T( 43) =  .181150E+04   T( 44) =  .177806E+04   T( 45) =  .182211E+04
T( 46) =  .184677E+04   T( 47) =  .182826E+04   T( 48) =  .175716E+04   T( 49) =  .154953E+04   T( 50) =  .151736E+04
T( 51) =  .204522E+04   T( 52) =  .195943E+04   T( 53) =  .176897E+04   T( 54) =  .166782E+04   T( 55) =  .179316E+04
T( 56) =  .181605E+04   T( 57) =  .177266E+04   T( 58) =  .167772E+04   T( 59) =  .144015E+04   T( 60) =  .137827E+04
T( 61) =  .204554E+04   T( 62) =  .195943E+04   T( 63) =  .177407E+04   T( 64) =  .163623E+04   T( 65) =  .155867E+04
T( 66) =  .158795E+04   T( 67) =  .155165E+04   T( 68) =  .143422E+04   T( 69) =  .133597E+04   T( 70) =  .129574E+04
```

Figure 5-8. Model 2A Output (Sheet 33 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

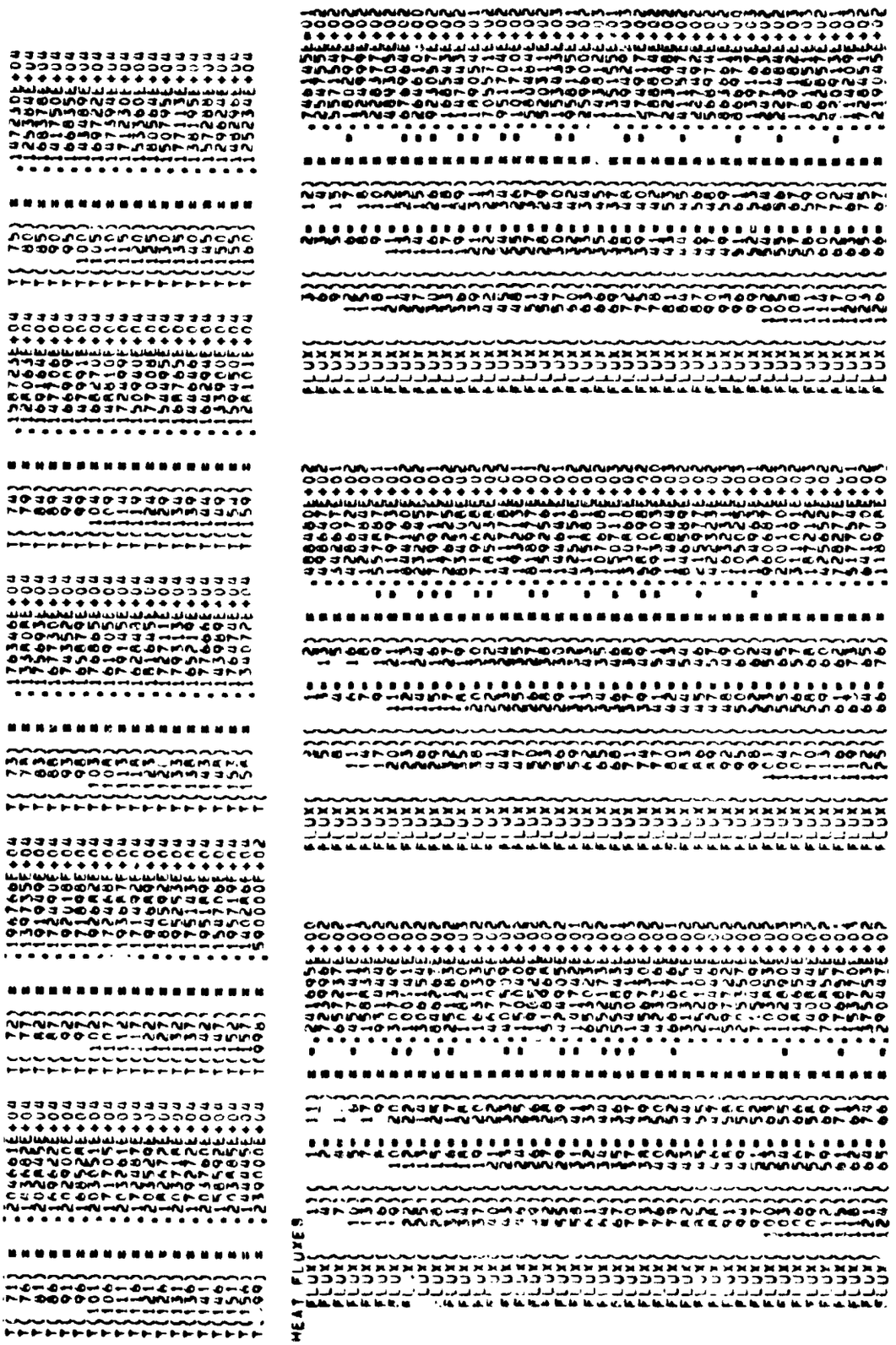


Figure 5-8. Model 2A Output (Sheet 34 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

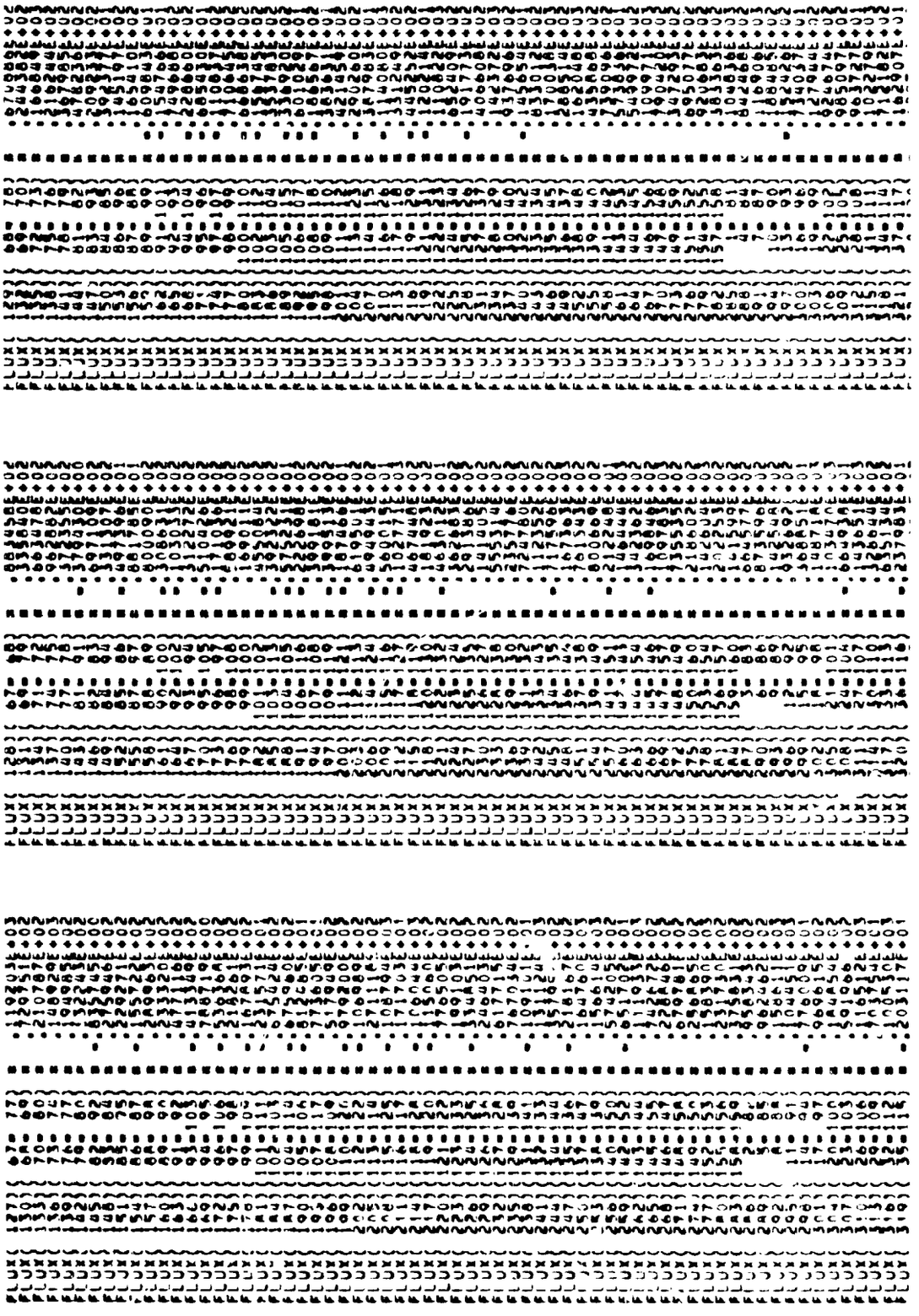


Figure 5-8. Model 2A Output (Sheet 35 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

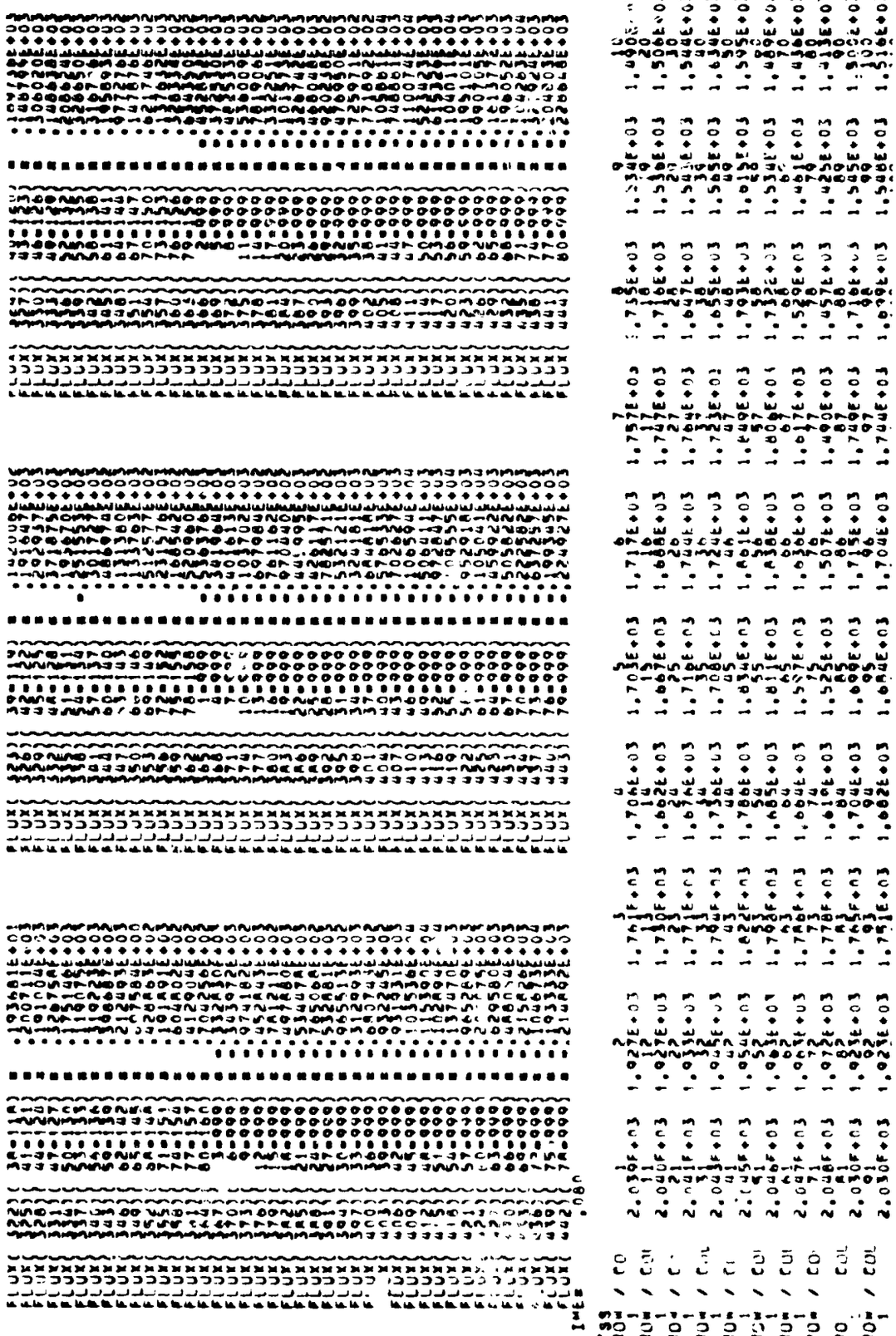
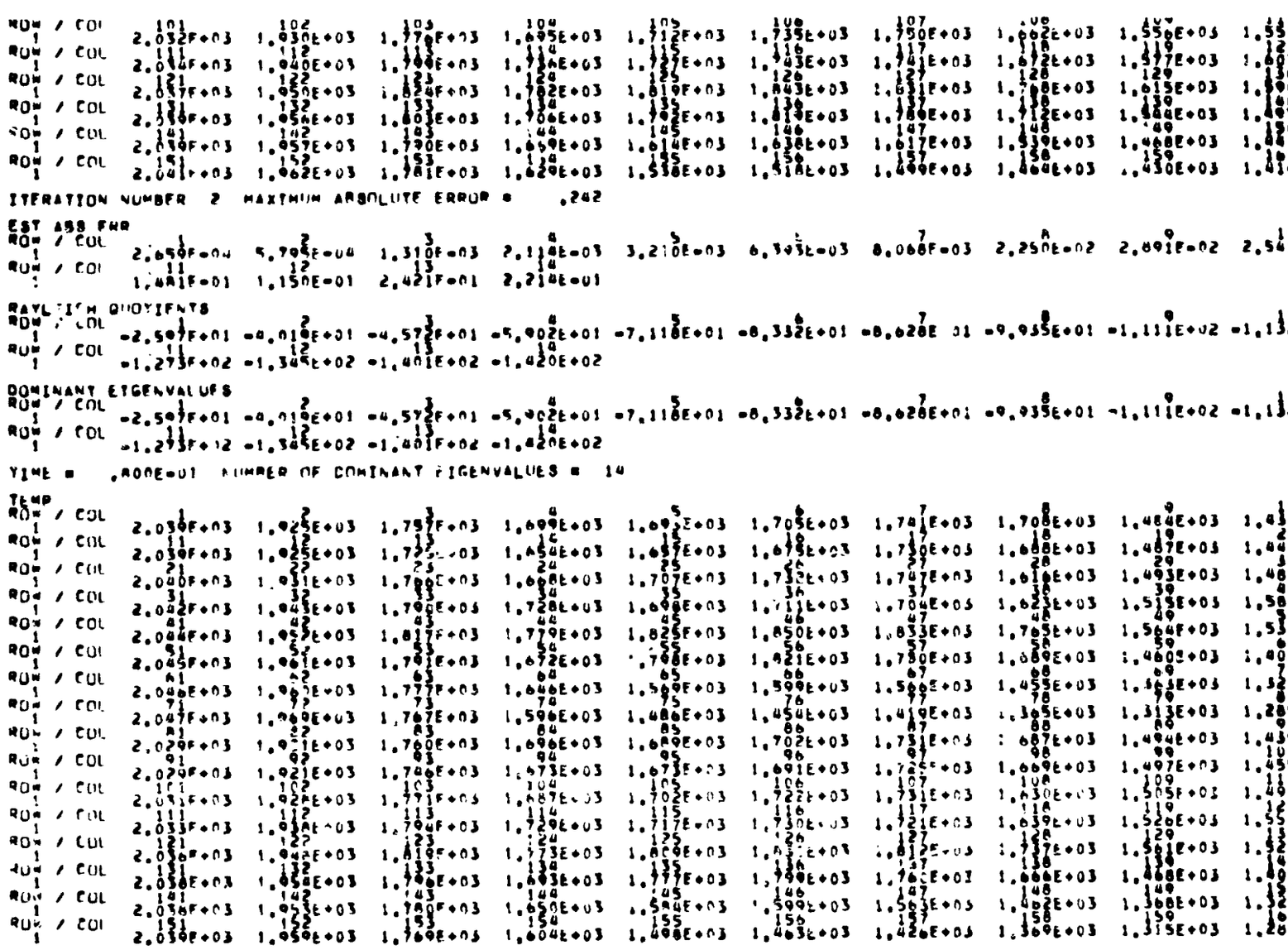


Figure 5-8. Model 2A Output (Sheet 36 of 49)



```
ROW / COL      101          102          103          104          105          106          107          108          109          110
  1        2.032F+03    1.030E+03    1.770E+03    1.695E+03    1.712F+03    1.735E+03    1.750E+03    1.662E+03    1.550E+03    1.551E+03
ROW / COL      111          112          113          114          115          116          117          118          119          120
  1        2.044F+03    1.040E+03    1.790E+03    1.714E+03    1.737E+03    1.743E+03    1.741E+03    1.672E+03    1.577E+03    1.607E+03
ROW / COL      121          122          123          124          125          126          127          128          129          130
  1        2.057F+03    1.050E+03    1.824F+03    1.782E+03    1.819F+03    1.843E+03    1.831F+03    1.788E+03    1.615E+03    1.690E+03
ROW / COL      131          132          133          134          135          136          137          138          139          140
  1        2.066F+03    1.054E+03    1.803E+03    1.784E+03    1.802E+03    1.815E+03    1.786E+03    1.712E+03    1.644E+03    1.697E+03
ROW / COL      141          142          143          144          145          146          147          148          149          150
  1        2.070F+03    1.057E+03    1.790E+03    1.699E+03    1.614E+03    1.638E+03    1.617E+03    1.539E+03    1.468E+03    1.482E+03
ROW / COL      151          152          153          154          155          156          157          158          159          160
  1        2.041F+03    1.062E+03    1.781E+03    1.629E+03    1.538E+03    1.518E+03    1.409E+03    1.464E+03    1.430E+03    1.416E+03

ITERATION NUMBER  2  MAXIMUM ABSOLUTE ERROR =     .242

EST ABS ERR
ROW / COL        1            2            3            4            5            6            7            8            9           10
  1        2.650F-04    5.795E-04    1.310F-03    2.114E-03    3.210E-03    6.395E-03    8.068F-03    2.250E-02    2.891E-02    2.541E-02
ROW / COL       11           12           13           14
  1        1.481F-01    1.150E-01    2.421F-01    2.214E-01

RAYLEIGH QUOTIENTS
ROW / COL        1            2            3            4            5            6            7            8            9           10
  1       -2.597F+01   -4.010E+01   -4.572F+01   -5.902E+01   -7.118E+01   -8.332E+01   -8.628E 01   -9.935E+01   -1.111E+02   -1.132E+02
ROW / COL       11           12           13           14
  1       -1.273F+02   -1.345E+02   -1.401E+02   -1.420E+02

DOMINANT EIGENVALUES
ROW / COL        1            2            3            4            5            6            7            8            9           10
  1       -2.597F+01   -4.010E+01   -4.572F+01   -5.902E+01   -7.118E+01   -8.332E+01   -8.628E+01   -9.935E+01   -1.111E+02   -1.132E+02
ROW / COL       11           12           13           14
  1       -1.273F+02   -1.345E+02   -1.401E+02   -1.420E+02

TIME =    .800E-01  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL        1            2            3            4            5            6            7            8            9           10
  1        2.030F+03    1.025E+03    1.757F+03    1.699E+03    1.699E+03    1.705E+03    1.741E+03    1.708E+03    1.484E+03    1.431E+03
ROW / COL       11           12           13           14           15           16           17           18           19           20
  1        2.030F+03    1.025E+03    1.725E+03    1.454E+03    1.657E+03    1.679E+03    1.710E+03    1.688E+03    1.487E+03    1.447E+03
ROW / COL       21           22           23           24           25           26           27           28           29           30
  1        2.040F+03    1.031E+03    1.780E+03    1.688E+03    1.707E+03    1.735E+03    1.747E+03    1.616E+03    1.493E+03    1.488E+03
ROW / COL       31           32           33           34           35           36           37           38           39           40
  1        2.042F+03    1.043E+03    1.790E+03    1.728E+03    1.698E+03    1.711E+03    1.704E+03    1.622E+03    1.515E+03    1.503E+03
ROW / COL       41           42           43           44           45           46           47           48           49           50
  1        2.044F+03    1.052E+03    1.817F+03    1.779E+03    1.825F+03    1.850E+03    1.833E+03    1.705E+03    1.564F+03    1.534E+03
ROW / COL       51           52           53           54           55           56           57           58           59           60
  1        2.045F+03    1.061E+03    1.791E+03    1.672E+03    1.708E+03    1.721E+03    1.730E+03    1.689E+03    1.460E+03    1.402E+03
ROW / COL       61           62           63           64           65           66           67           68           69           70
  1        2.046E+03    1.069E+03    1.777F+03    1.646E+03    1.569E+03    1.599E+03    1.556E+03    1.455E+03    1.363E+03    1.327E+03
ROW / COL       71           72           73           74           75           76           77           78           79           80
  1        2.047F+03    1.069E+03    1.767E+03    1.596E+03    1.486E+03    1.454E+03    1.410E+03    1.305E+03    1.313E+03    1.289E+03
ROW / COL       81           82           83           84           85           86           87           88           89           90
  1        2.029F+03    1.021E+03    1.760E+03    1.696E+03    1.689E+03    1.702E+03    1.731E+03    1.687E+03    1.494E+03    1.439E+03
ROW / COL       91           92           93           94           95           96           97           98           99          100
  1        2.029F+03    1.021E+03    1.746E+03    1.673E+03    1.673E+03    1.691E+03    1.725E+03    1.669E+03    1.497E+03    1.455E+03
ROW / COL      101          102          103          104          105          106          107          108          109          110
  1        2.031F+03    1.022E+03    1.771E+03    1.687E+03    1.702E+03    1.722E+03    1.731E+03    1.630E+03    1.505F+03    1.493E+03
ROW / COL      111          112          113          114          115          116          117          118          119          120
  1        2.033F+03    1.034E+03    1.794F+03    1.729E+03    1.717E+03    1.730E+03    1.721E+03    1.639E+03    1.526E+03    1.551E+03
ROW / COL      121          122          123          124          125          126          127          128          129          130
  1        2.056F+03    1.044E+03    1.810F+03    1.773E+03    1.809E+03    1.833E+03    1.812E+03    1.757E+03    1.561E+03    1.527E+03
ROW / COL      131          132          133          134          135          136          137          138          139          140
  1        2.058E+03    1.054E+03    1.790E+03    1.693E+03    1.777E+03    1.796E+03    1.766E+03    1.666E+03    1.468E+03    1.498E+03
ROW / COL      141          142          143          144          145          146          147          148          149          150
  1        2.058F+03    1.055E+03    1.780F+03    1.650E+03    1.594E+03    1.599E+03    1.563E+03    1.462E+03    1.368E+03    1.329E+03
ROW / COL      151          152          153          154          155          156          157          158          159          160
  1        2.039F+03    1.059E+03    1.769E+03    1.604E+03    1.498E+03    1.463E+03    1.426E+03    1.369E+03    1.315E+03    1.289E+03
```

Figure 5-8. Model 2A Output (Sheet 37 of 49)

REPRODUCIBILITY OF THE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

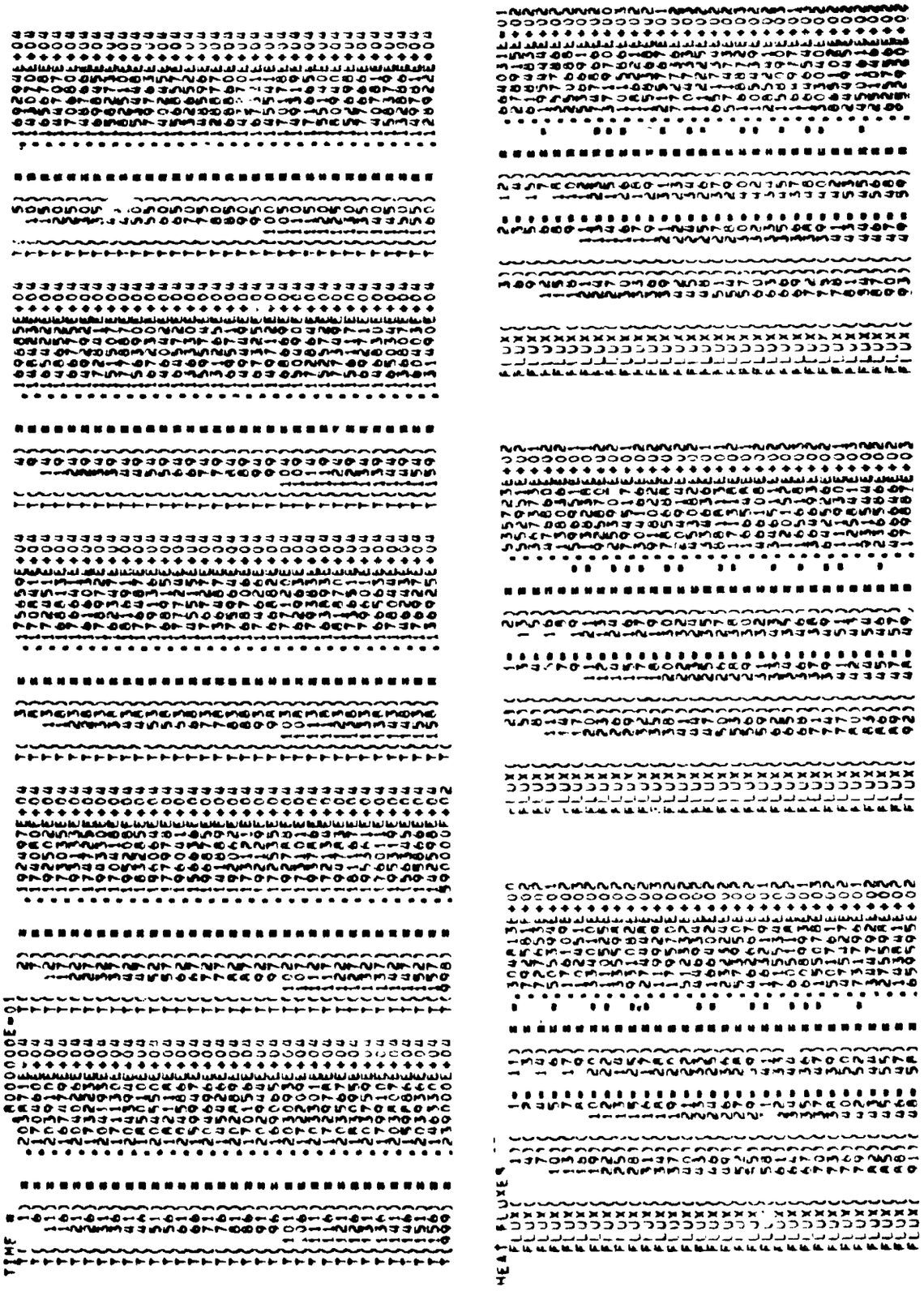


Figure 5-8. Model 2A Output (Sheet 38 of 49)

C-2

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

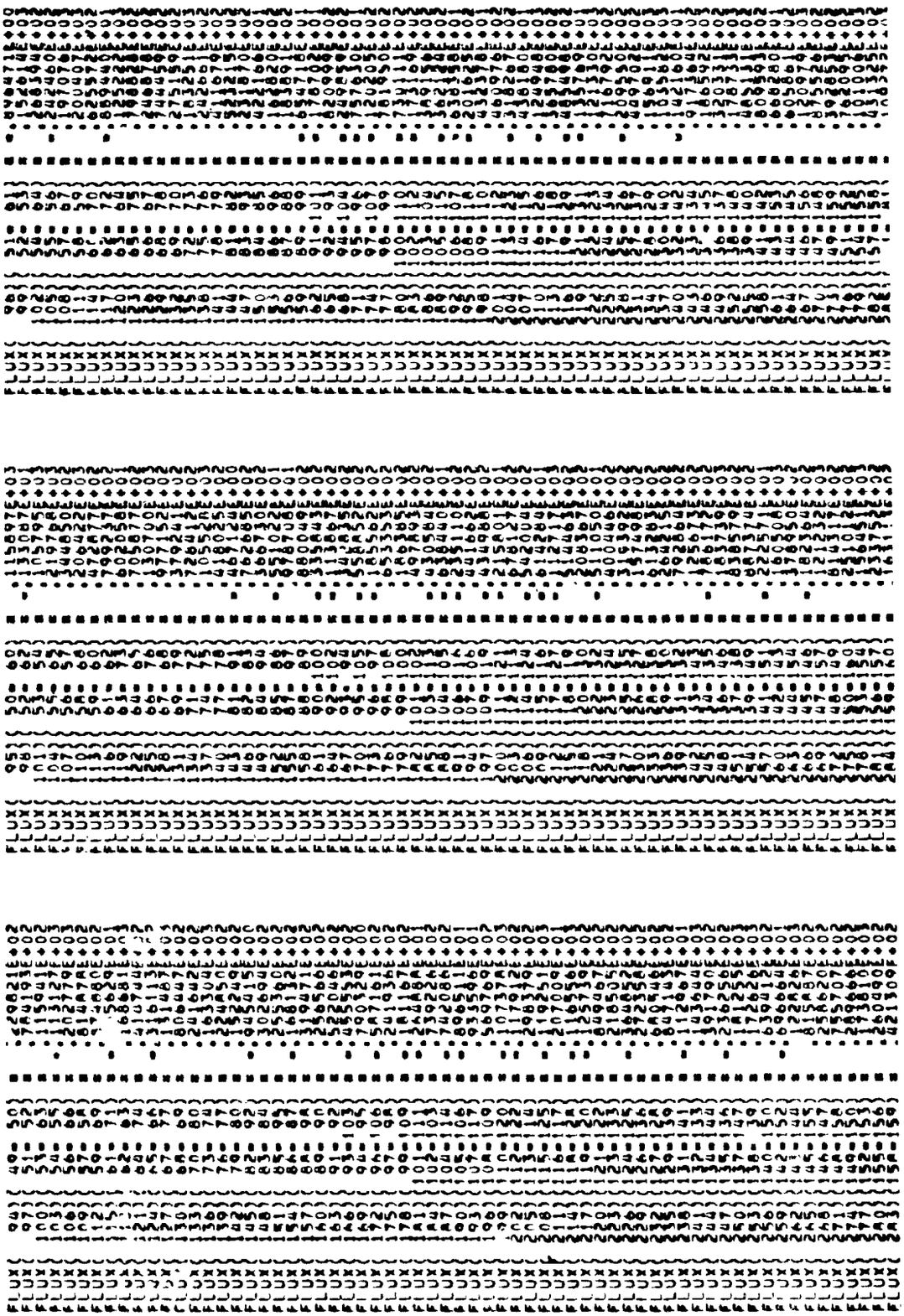


Figure 5-8. Model 2A Output (Sheet 39 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

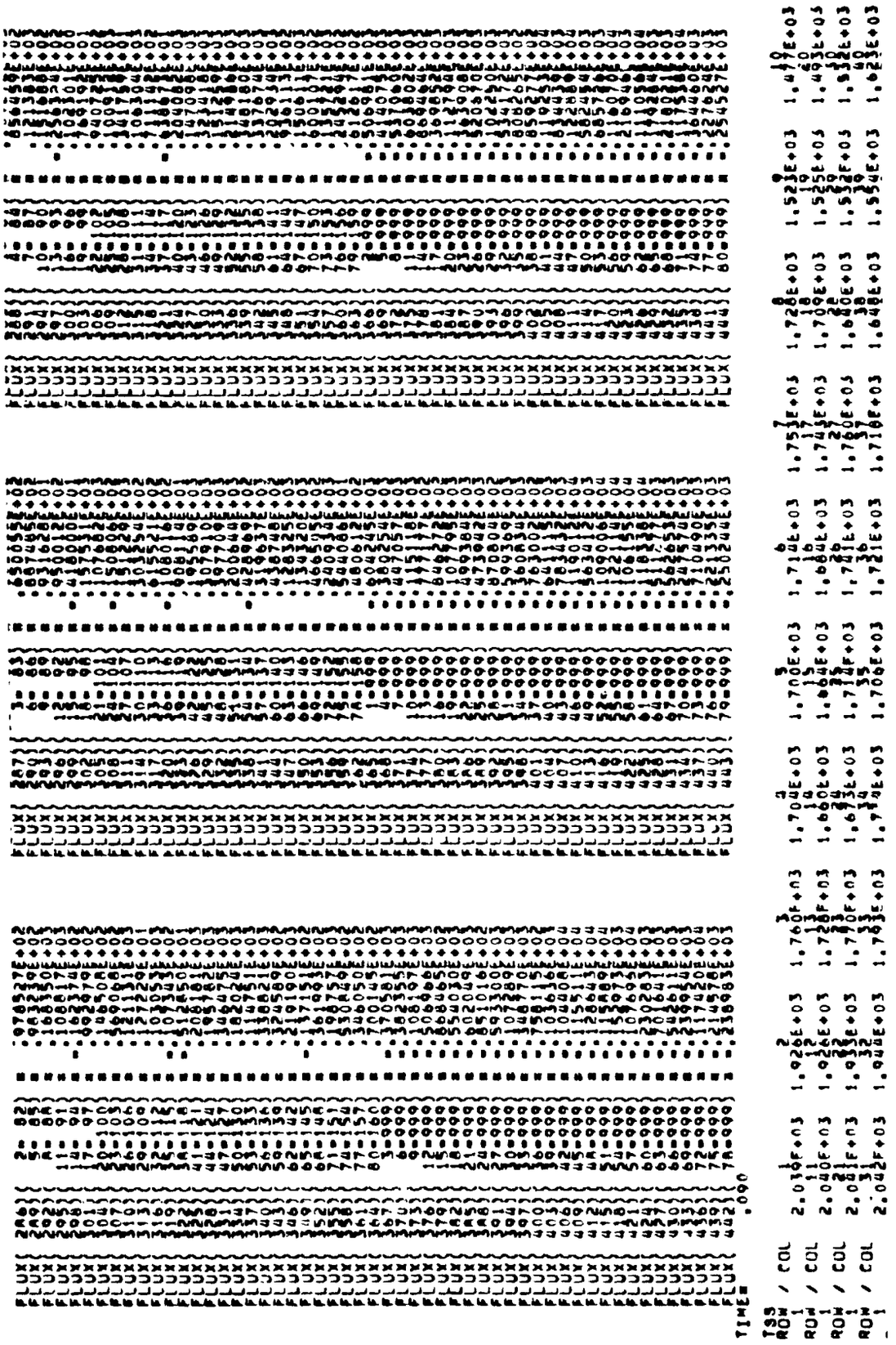


Figure 5-8. Model 2A Output (Sheet 40 of 49)

```
ROW / COL      41          42          43          44          45          46          47          48          49          50
   1       2.044F+03   1.955E+03   1.820F+03   1.784E+03   1.831E+03   1.858E+03   1.845E+03   1.787E+03   1.604E+03   1.582E+03
ROW / COL      51          52          53          54          55          56          57          58          59          60
   1       2.046F+03   1.962E+03   1.796F+03   1.681E+03   1.808E+03   1.834E+03   1.800E+03   1.723E+03   1.519E+03   1.472E+03
ROW / COL      61          62          63          64          65          66          67          68          69          70
   1       2.047F+03   1.962E+03   1.784F+03   1.659E+03   1.591E+03   1.628E+03   1.606E+03   1.515E+03   1.442E+03   1.416E+03
ROW / COL      71          72          73          74          75          76          77          78          79          80
   1       2.048E+03   1.971E+03   1.775F+03   1.614E+03   1.516E+03   1.496E+03   1.475E+03   1.439E+03   1.405E+03   1.391E+03
ROW / COL      81          82          83          84          85          86          87          88          89          90
   1       2.029F+03   1.922E+03   1.763E+03   1.701E+03   1.696E+03   1.711E+03   1.745E+03   1.710E+03   1.535E+03   1.487E+03
ROW / COL      91          92          93          94          95          96          97          98          99         100
   1       2.030F+03   1.923E+03   1.750E+03   1.679E+03   1.681E+03   1.701E+03   1.739E+03   1.692E+03   1.537E+03   1.503E+03
ROW / COL     101         102         103         104         105         106         107         108         109         110
   1       2.032F+03   1.929E+03   1.775E+03   1.693E+03   1.709E+03   1.732E+03   1.745E+03   1.655E+03   1.545E+03   1.539E+03
ROW / COL     111         112         113         114         115         116         117         118         119         120
   1       2.034F+03   1.939E+03   1.797E+03   1.734E+03   1.724E+03   1.740E+03   1.737E+03   1.665E+03   1.566E+03   1.596E+03
ROW / COL     121         122         123         124         125         126         127         128         129         130
   1       2.036F+03   1.949E+03   1.822E+03   1.779E+03   1.817E+03   1.840E+03   1.826F+03   1.762E+03   1.604E+03   1.578E+03
ROW / COL     131         132         133         134         135         136         137         138         139         140
   1       2.038F+03   1.956E+03   1.801E+03   1.702E+03   1.788E+03   1.814E+03   1.783E+03   1.703E+03   1.529E+03   1.480E+03
ROW / COL     141         142         143         144         145         146         147         148         149         150
   1       2.039F+03   1.956E+03   1.788E+03   1.665E+03   1.607E+03   1.629E+03   1.606E+03   1.524E+03   1.450E+03   1.421E+03
ROW / COL     151         152         153         154         155         156         157         158         159         160
   1       2.040E+03   1.961E+03   1.778E+03   1.623E+03   1.529E+03   1.507E+03   1.485E+03   1.446E+03   1.410E+03   1.394E+03

ITERATION NUMBER  2  MAXIMUM ABSOLUTE ERROR =     .201

EST ABS ERR
ROW / COL       1           2           3           4           5           6           7           8           9          10
   1       1.820E-04   3.520E-04   7.562E-04   1.181E-03   2.039E-03   4.007E-03   5.684E-03   1.287E-02   2.114E-02   1.879E-02
ROW / COL      11          12          13          14
   1       1.348F-01   1.015E-01   1.999F-01   2.011E-01

RAYLEIGH QUOTIENTS
ROW / COL       1           2           3           4           5           6           7           8           9          10
   1      -2.624E+01  -4.039E+01  -4.588E+01  -5.910E+01  -7.133E+01  -8.348E+01  -8.640E+01  -9.946E+01  -1.111E+02  -1.133E+02
ROW / COL      11          12          13          14
   1      -1.274E+02  -1.346E+02  -1.402E+02  -1.421E+02

DOMINANT EIGENVALUES
ROW / COL       1           2           3           4           5           6           7           8           9          10
   1      -2.624F+01  -4.039E+01  -4.588E+01  -5.910E+01  -7.133F+01  -8.348E+01  -8.640E+01  -9.946E+01  -1.111E+02  -1.133E+02
ROW / COL      11          12          13          14
   1      -1.274E+02  -1.346E+02  -1.402E+02  -1.421E+02

TIME =    .900E-01   NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL       1           2           3           4           5           6           7           8           9          10
   1       2.039F+03   1.925E+03   1.758F+03   1.700E+03   1.695E+03   1.707E+03   1.744E+03   1.713E+03   1.493E+03   1.442E+03
ROW / COL      11          12          13          14          15          16          17          18          19          20
   1       2.039E+03   1.925E+03   1.726E+03   1.656E+03   1.659E+03   1.677E+03   1.733E+03   1.693E+03   1.496E+03   1.458E+03
ROW / COL      21          22          23          24          25          26          27          28          29          30
   1       2.040F+03   1.933E+03   1.767E+03   1.669E+03   1.709E+03   1.734E+03   1.750E+03   1.621E+03   1.502F+03   1.498E+03
ROW / COL      31          32          33          34          35          36          37          38          39          40
   1       2.042F+03   1.944E+03   1.791E+03   1.730E+03   1.700E+03   1.714E+03   1.707E+03   1.629E+03   1.524F+03   1.592E+03
```

Figure 5-8. Model 2A Output (Sheet 41 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

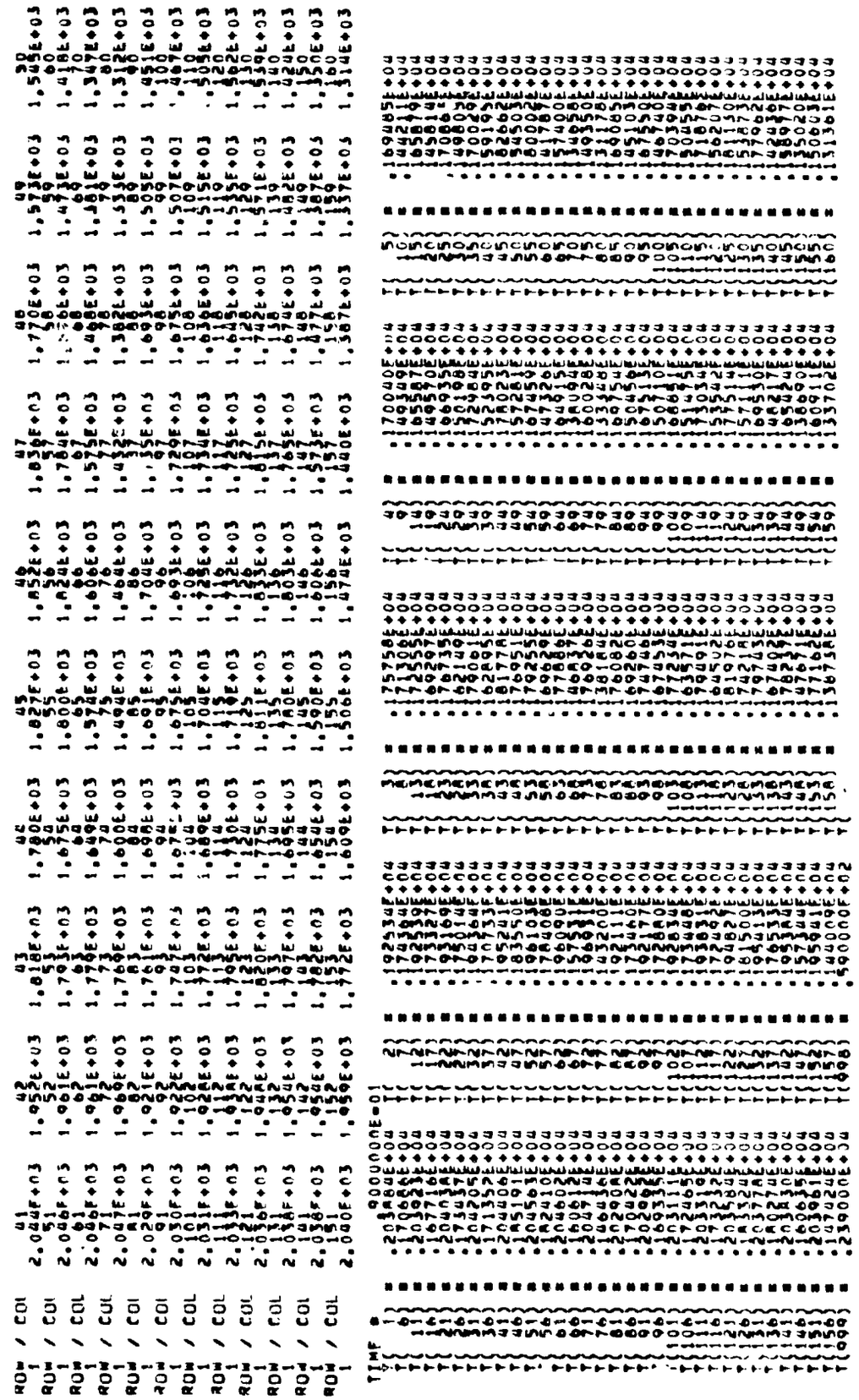


Figure 5-6. Model 2A Output (Sheet 42 of 49)

```
ITERATION NUMBER  2  MAXIMUM ABSOLUTE ERROR =    .178

EST ABS ERR
ROW / COL          1          2          3          4          5          6          7          8          9         10
    1       1.187E-04  2.102E-04  4.259E-04  6.463E-04  1.507E-03  2.472E-03  3.989E-03  7.492E-03  1.490E-02  1.446E-02
ROW / COL         11         12         13         14
    1       1.149E-01  8.405E-02  1.652E-01  1.776E-01

RAYLEIGH QUOTIENTS
ROW / COL          1          2          3          4          5          6          7          8          9         10
    1      -2.642E+01 -4.051E+01 -4.597E+01 -5.914E+01 -7.142E+01 -8.359E+01 -8.647E+01 -9.953E+01 -1.112E+02 -1.133E+02
ROW / COL         11         12         13         14
    1      -1.275E+02 -1.347E+02 -1.402E+02 -1.422E+02

DOMINANT EIGENVALUES
ROW / COL          1          2          3          4          5          6          7          8          9         10
    1      -2.642E+01 -4.051E+01 -4.597E+01 -5.914E+01 -7.142E+01 -8.359E+01 -8.647E+01 -9.953E+01 -1.112E+02 -1.133E+02
ROW / COL         11         12         13         14
    1      -1.275E+02 -1.347E+02 -1.402E+02 -1.422E+02

TIME =    .100E+00  NUMBER OF DOMINANT EIGENVALUES =  14

TEMP
ROW / COL          1          2          3          4          5          6          7          8          9         10
    1       2.039E+03  1.926E+03  1.758E+03  1.701E+03  1.696E+03  1.708E+03  1.745E+03  1.716E+03  1.499E+03  1.449E+03
ROW / COL         11         12         13         14         15         16         17         18         19         20
    1       2.039E+03  1.924E+03  1.726E+03  1.657E+03  1.640E+03  1.678E+03  1.735E+03  1.696E+03  1.501E+03  1.465E+03
ROW / COL         21         22         23         24         25         26         27         28         29         30
    1       2.040E+03  1.932E+03  1.768E+03  1.670E+03  1.710E+03  1.736E+03  1.752E+03  1.625E+03  1.507E+03  1.504E+03
ROW / COL         31         32         33         34         35         36         37         38         39         40
    1       2.042E+03  1.944E+03  1.791E+03  1.731E+03  1.701E+03  1.715E+03  1.709E+03  1.632E+03  1.529E+03  1.507E+03
ROW / COL         41         42         43         44         45         46         47         48         49         50
    1       2.044E+03  1.953E+03  1.818E+03  1.781E+03  1.827E+03  1.853E+03  1.837E+03  1.772E+03  1.578E+03  1.552E+03
ROW / COL         51         52         53         54         55         56         57         58         59         60
    1       2.046E+03  1.961E+03  1.793E+03  1.676E+03  1.801E+03  1.826E+03  1.787E+03  1.701E+03  1.481E+03  1.422E+03
ROW / COL         61         62         63         64         65         66         67         68         69         70
    1       2.046E+03  1.961E+03  1.780E+03  1.651E+03  1.577E+03  1.610E+03  1.581E+03  1.477E+03  1.392E+03  1.359E+03
ROW / COL         71         72         73         74         75         76         77         78         79         80
    1       2.047E+03  1.970E+03  1.770E+03  1.603E+03  1.498E+03  1.470E+03  1.440E+03  1.392E+03  1.347E+03  1.327E+03
ROW / COL         81         82         83         84         85         86         87         88         89         90
    1       2.029E+03  1.921E+03  1.761E+03  1.698E+03  1.692E+03  1.706E+03  1.736E+03  1.696E+03  1.510E+03  1.456E+03
ROW / COL         91         92         93         94         95         96         97         98         99        100
    1       2.030E+03  1.922E+03  1.748E+03  1.676E+03  1.677E+03  1.695E+03  1.731E+03  1.678E+03  1.513E+03  1.474E+03
ROW / COL        101        102        103        104        105        106        107        108        109        110
    1       2.031E+03  1.929E+03  1.773E+03  1.689E+03  1.705E+03  1.726E+03  1.736E+03  1.639E+03  1.521E+03  1.511E+03
ROW / COL        111        112        113        114        115        116        117        118        119        120
    1       2.033E+03  1.939E+03  1.795E+03  1.731E+03  1.720E+03  1.734E+03  1.727E+03  1.649E+03  1.541E+03  1.508E+03
ROW / COL        121        122        123        124        125        126        127        128        129        130
    1       2.036E+03  1.948E+03  1.820E+03  1.776E+03  1.812E+03  1.835E+03  1.817E+03  1.740E+03  1.577E+03  1.546E+03
ROW / COL        131        132        133        134        135        136        137        138        139        140
    1       2.038E+03  1.954E+03  1.798E+03  1.697E+03  1.741E+03  1.805E+03  1.768E+03  1.679E+03  1.491E+03  1.435E+03
ROW / COL        141        142        143        144        145        146        147        148        149        150
    1       2.039E+03  1.954E+03  1.783E+03  1.656E+03  1.593E+03  1.611E+03  1.580E+03  1.486E+03  1.399E+03  1.364E+03
ROW / COL        151        152        153        154        155        156        157        158        159        160
    1       2.040E+03  1.960E+03  1.773E+03  1.612E+03  1.511E+03  1.481E+03  1.449E+03  1.399E+03  1.351E+03  1.329E+03

 TIME =     .1000000E+00
 T(   1) =  .2039A90E+04   T(   2) =  .1925S1E+04   T(   3) =  .1758O3E+04   T(   4) =  .1701I2E+04   T(   5) =  .1695Z8E+04
 T(   6) =  .1708A0AE+04   T(   7) =  .1745Z1E+04   T(   8) =  .1715Z2E+04   T(   9) =  .1499B5E+04   T(  10) =  .1448Z5E+04
 T(  11) =  .2039Z9E+04   T(  12) =  .1925S5E+04   T(  13) =  .1726O3E+04   T(  14) =  .1656B4E+04   T(  15) =  .1659Z7E+04
 T(  16) =  .1678A9E+04   T(  17) =  .1734A0E+04   T(  18) =  .1665Z6E+04   T(  19) =  .1501O4E+04   T(  20) =  .1460I1E+04
 T(  21) =  .2040A4E+04   T(  22) =  .1931A5E+04   T(  23) =  .1767Z9E+04   T(  24) =  .1670I0E+04   T(  25) =  .1709S3E+04
 T(  26) =  .1735S0E+04   T(  27) =  .1751Z6E+04   T(  28) =  .1626Z6E+04   T(  29) =  .1507S6E+04   T(  30) =  .1504I7E+04
 T(  31) =  .2042I0E+04   T(  32) =  .1943Z9E+04   T(  33) =  .1791O3E+04   T(  34) =  .1731O3E+04   T(  35) =  .1701Z1E+04
```

Figure 5-8. Model 2A Output (Sheet 43 of 49)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

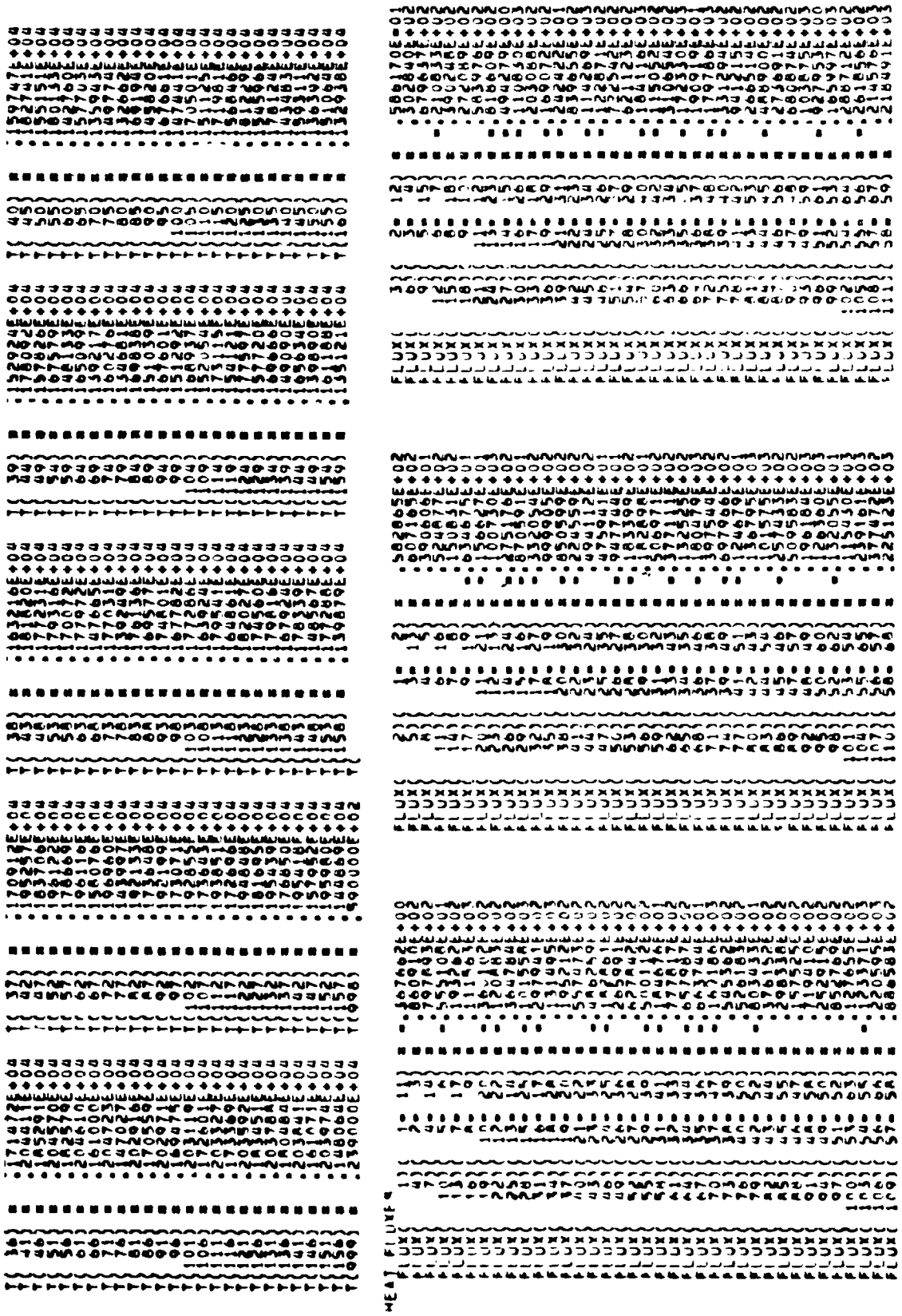


Figure 5-8. Model 2A Output (Sheet 44 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

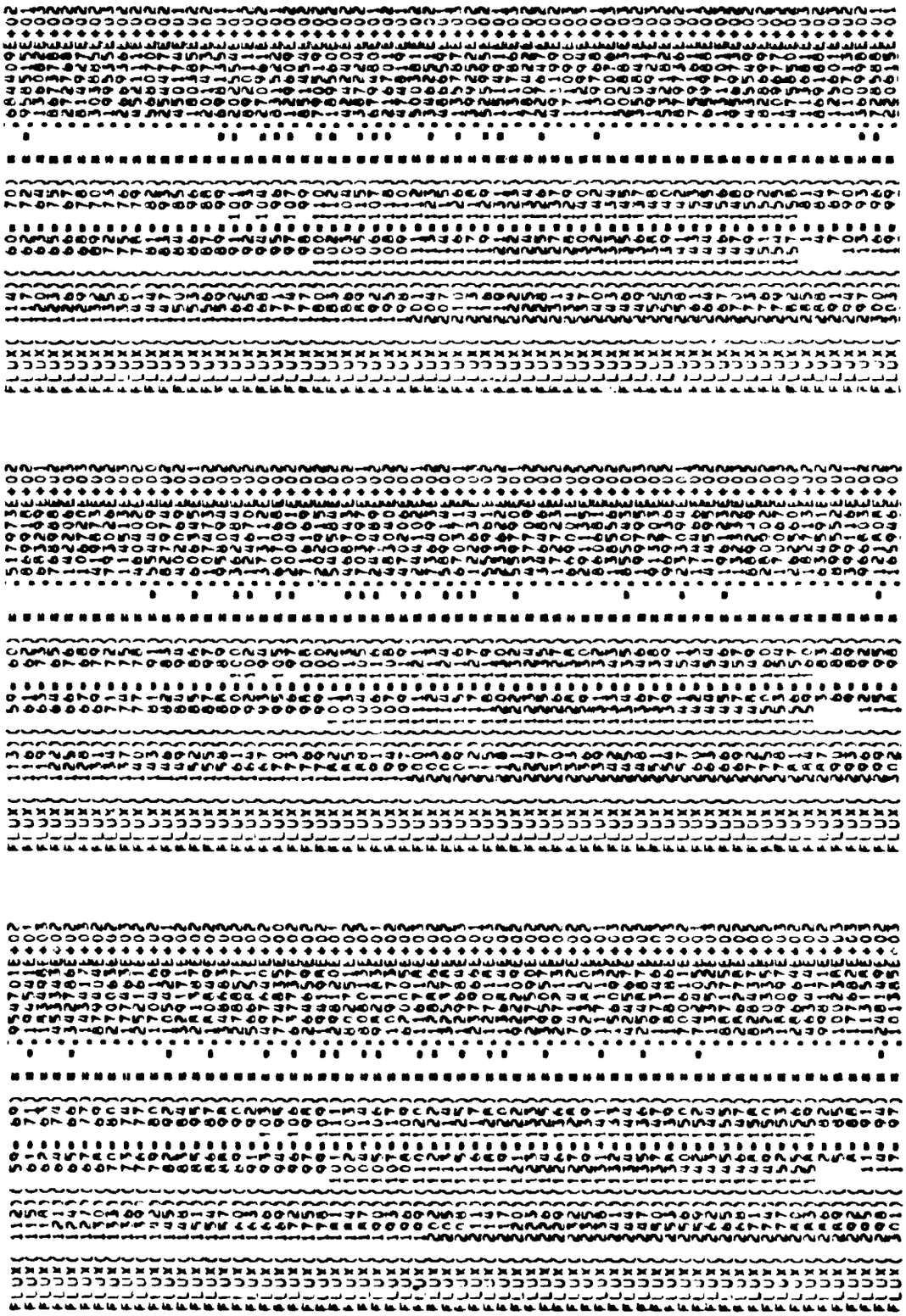


Figure 3-5. Model 2A Output (Sheet 45 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Figure 5-8. Model 2A Output (Sheet 46 of 49)

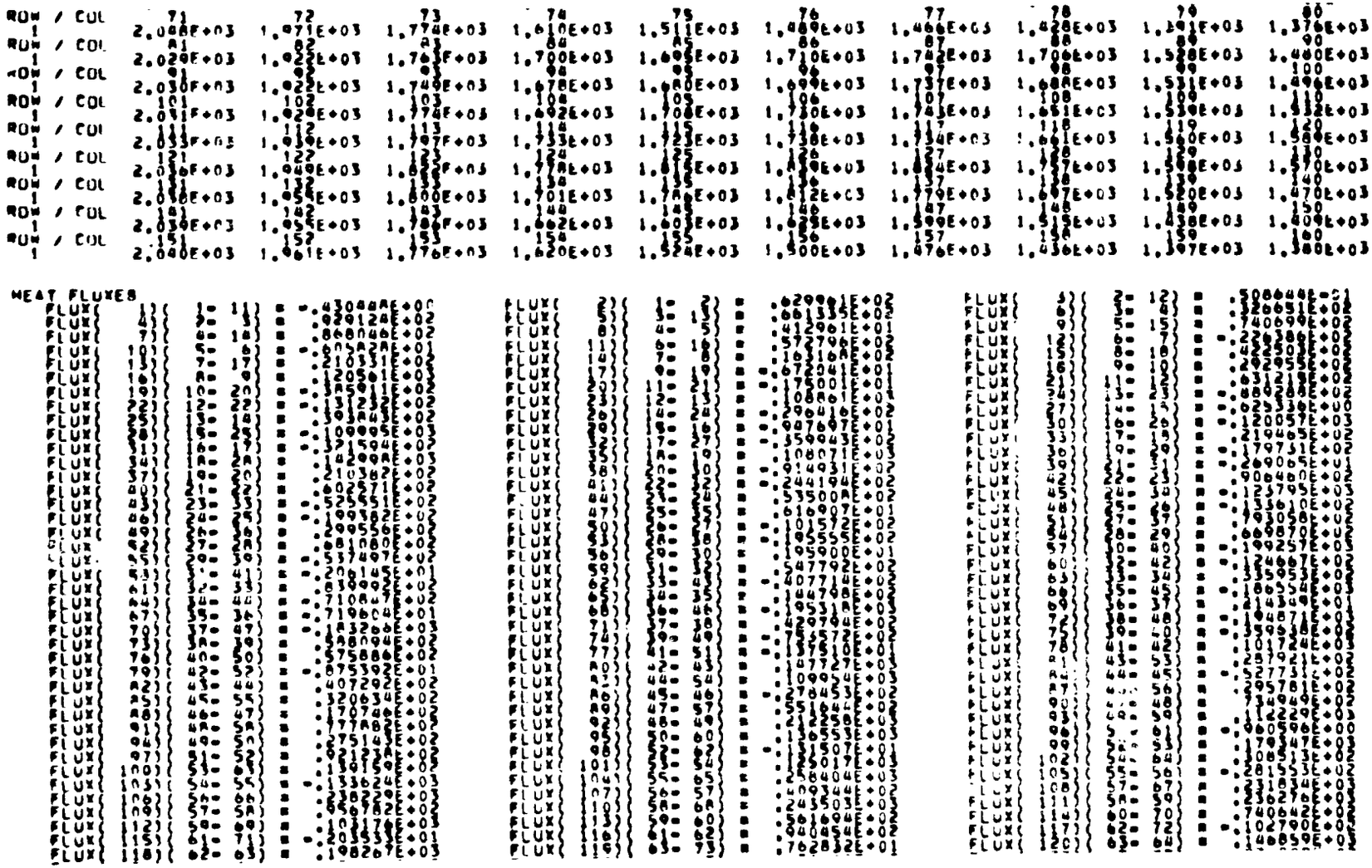


Figure 5-8. Model 2A Output (Sheet 47 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

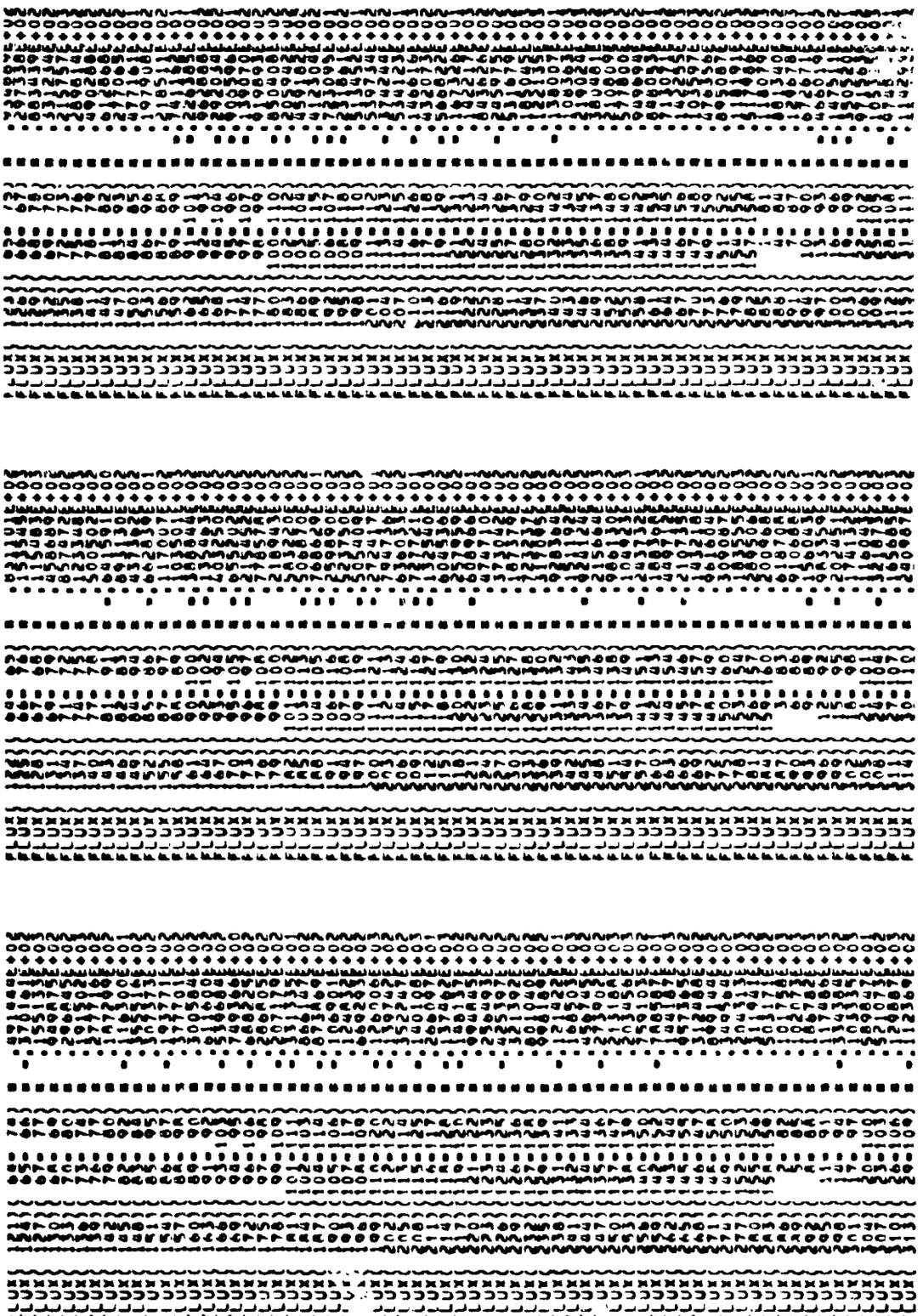


Figure 5-5. Model 2A Output (Sheet 48 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

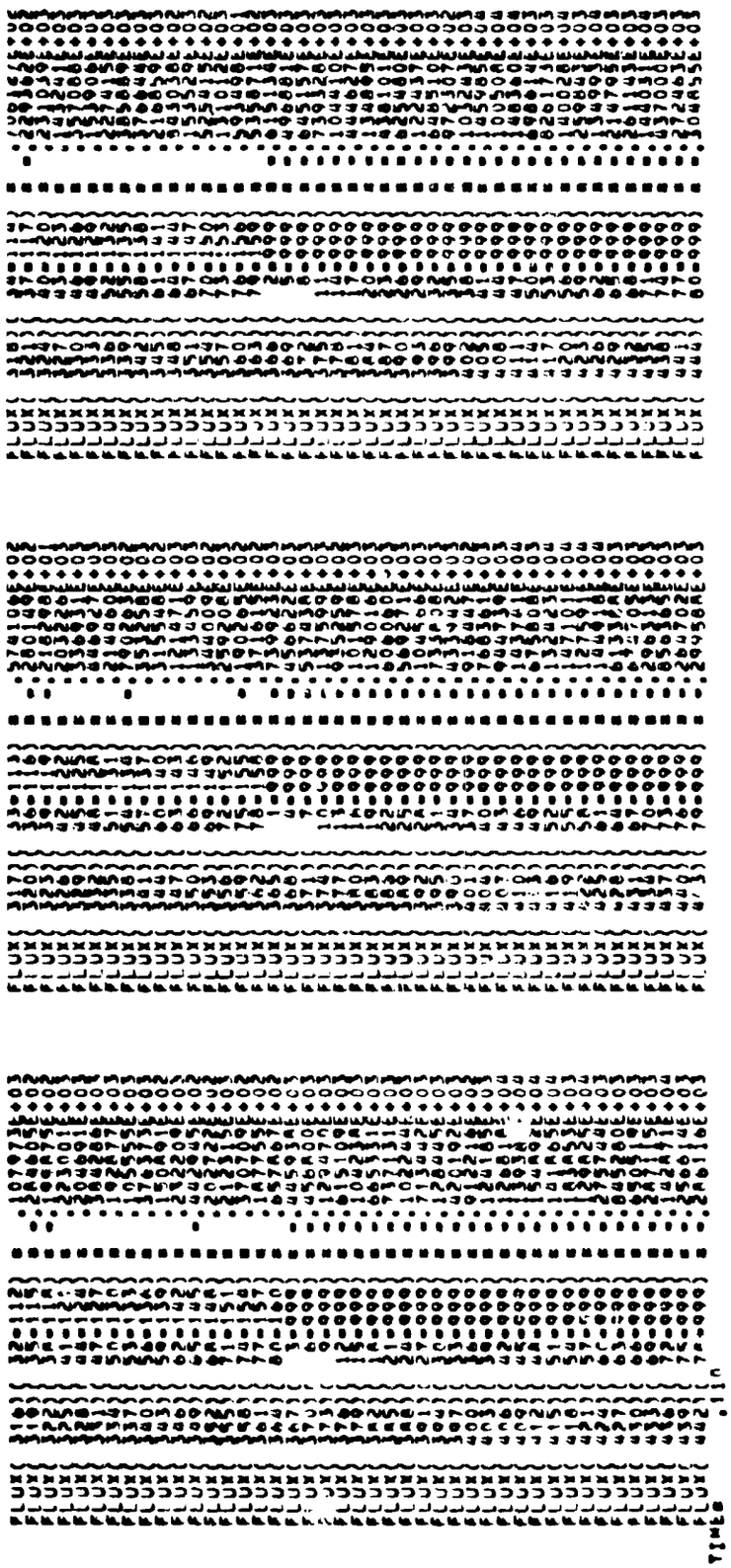


Figure 5-7. Model 2A Output (Sheet 49 of 49)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

```
$STORE
NUMBND = 2,
NUMITR = 260,
NUMCON = 700,
NUMTCN = 1960
NUMNOD = 1000,
NUMFIX = 0,
NSTH   = 15000,
NEVALU = 14,
NUMTNT = 262,
NUMSCH = 2196,
NUMMAD = 40,
$END
```


Figure 5-9. Model 2B Output (Sheet 1 of 16)

```
LANGLEY
      MODEL  TMU
        RUN 2  B SECTION

NUMBER OF ITERATED NODES    =    256
NUMBER OF BOUNDARY NODES    =      2
NUMBER OF CONDUCTION LINKS  =    696
NUMBER OF RADIATION LINKS   =     80
NUMBER OF HEAT SOURCES      =      0

TIME = 0.                    DTIME =  .10000000E-01      PTIME =  .10000000E+00

INITIAL TEMPERATURES OF ITERATED NODES
   T(  1) =  .5000000E+03  T(  2) =  .5000000E+03  T(  3) =  .5000000E+03  T(  4) =  .5000000E+03  T(  5) =  .5000000E+03
   T(  6) =  .5000000E+03  T(  7) =  .5000000E+03  T(  8) =  .5000000E+03  T(  9) =  .5000000E+03  T( 10) =  .5000000E+03
   T( 11) =  .5000000E+03  T( 12) =  .5000000E+03  T( 13) =  .5000000E+03  T( 14) =  .5000000E+03  T( 15) =  .5000000E+03
   T( 16) =  .5000000E+03  T( 17) =  .5000000E+03  T( 18) =  .5000000E+03  T( 19) =  .5000000E+03  T( 20) =  .5000000E+03
   T( 21) =  .5000000E+03  T( 22) =  .5000000E+03  T( 23) =  .5000000E+03  T( 24) =  .5000000E+03  T( 25) =  .5000000E+03
   T( 26) =  .5000000E+03  T( 27) =  .5000000E+03  T( 28) =  .5000000E+03  T( 29) =  .5000000E+03  T( 30) =  .5000000E+03
   T( 31) =  .5000000E+03  T( 32) =  .5000000E+03  T( 33) =  .5000000E+03  T( 34) =  .5000000E+03  T( 35) =  .5000000E+03
   T( 36) =  .5000000E+03  T( 37) =  .5000000E+03  T( 38) =  .5000000E+03  T( 39) =  .5000000E+03  T( 40) =  .5000000E+03
   T( 41) =  .5000000E+03  T( 42) =  .5000000E+03  T( 43) =  .5000000E+03  T( 44) =  .5000000E+03  T( 45) =  .5000000E+03
   T( 46) =  .5000000E+03  T( 47) =  .5000000E+03  T( 48) =  .5000000E+03  T( 49) =  .5000000E+03  T( 50) =  .5000000E+03
   T( 51) =  .5000000E+03  T( 52) =  .5000000E+03  T( 53) =  .5000000E+03  T( 54) =  .5000000E+03  T( 55) =  .5000000E+03
   T( 56) =  .5000000E+03  T( 57) =  .5000000E+03  T( 58) =  .5000000E+03  T( 59) =  .5000000E+03  T( 60) =  .5000000E+03
   T( 61) =  .5000000E+03  T( 62) =  .5000000E+03  T( 63) =  .5000000E+03  T( 64) =  .5000000E+03  T( 65) =  .5000000E+03
   T( 66) =  .5000000E+03  T( 67) =  .5000000E+03  T( 68) =  .5000000E+03  T( 69) =  .5000000E+03  T( 70) =  .5000000E+03
   T( 71) =  .5000000E+03  T( 72) =  .5000000E+03  T( 73) =  .5000000E+03  T( 74) =  .5000000E+03  T( 75) =  .5000000E+03
   T( 76) =  .5000000E+03  T( 77) =  .5000000E+03  T( 78) =  .5000000E+03  T( 79) =  .5000000E+03  T( 80) =  .5000000E+03
   T( 81) =  .5000000E+03  T( 82) =  .5000000E+03  T( 83) =  .5000000E+03  T( 84) =  .5000000E+03  T( 85) =  .5000000E+03
   T( 86) =  .5000000E+03  T( 87) =  .5000000E+03  T( 88) =  .5000000E+03  T( 89) =  .5000000E+03  T( 90) =  .5000000E+03
   T( 91) =  .5000000E+03  T( 92) =  .5000000E+03  T( 93) =  .5000000E+03  T( 94) =  .5000000E+03  T( 95) =  .5000000E+03
   T( 96) =  .5000000E+03  T( 97) =  .5000000E+03  T( 98) =  .5000000E+03  T( 99) =  .5000000E+03  T(100) =  .5000000E+03

   T(101) =  .5000000E+03  T(102) =  .5000000E+03  T(103) =  .5000000E+03  T(104) =  .5000000E+03  T(105) =  .5000000E+03
   T(106) =  .5000000E+03  T(107) =  .5000000E+03  T(108) =  .5000000E+03  T(109) =  .5000000E+03  T(110) =  .5000000E+03
   T(111) =  .5000000E+03  T(112) =  .5000000E+03  T(113) =  .5000000E+03  T(114) =  .5000000E+03  T(115) =  .5000000E+03
   T(116) =  .5000000E+03  T(117) =  .5000000E+03  T(118) =  .5000000E+03  T(119) =  .5000000E+03  T(120) =  .5000000E+03
   T(121) =  .5000000E+03  T(122) =  .5000000E+03  T(123) =  .5000000E+03  T(124) =  .5000000E+03  T(125) =  .5000000E+03
   T(126) =  .5000000E+03  T(127) =  .5000000E+03  T(128) =  .5000000E+03  T(129) =  .5000000E+03  T(130) =  .5000000E+03
   T(131) =  .5000000E+03  T(132) =  .5000000E+03  T(133) =  .5000000E+03  T(134) =  .5000000E+03  T(135) =  .5000000E+03
   T(136) =  .5000000E+03  T(137) =  .5000000E+03  T(138) =  .5000000E+03  T(139) =  .5000000E+03  T(140) =  .5000000E+03
   T(141) =  .5000000E+03  T(142) =  .5000000E+03  T(143) =  .5000000E+03  T(144) =  .5000000E+03  T(145) =  .5000000E+03

   T(146) =  .5000000E+03  T(147) =  .5000000E+03  T(148) =  .5000000E+03  T(149) =  .5000000E+03  T(150) =  .5000000E+03
   T(151) =  .5000000E+03  T(152) =  .5000000E+03  T(153) =  .5000000E+03  T(154) =  .5000000E+03  T(155) =  .5000000E+03
   T(156) =  .5000000E+03  T(157) =  .5000000E+03  T(158) =  .5000000E+03  T(159) =  .5000000E+03  T(160) =  .5000000E+03
   T(161) =  .5000000E+03  T(162) =  .5000000E+03  T(163) =  .5000000E+03  T(164) =  .5000000E+03  T(165) =  .5000000E+03
   T(166) =  .5000000E+03  T(167) =  .5000000E+03  T(168) =  .5000000E+03  T(169) =  .5000000E+03  T(170) =  .5000000E+03
   T(171) =  .5000000E+03  T(172) =  .5000000E+03  T(173) =  .5000000E+03  T(174) =  .5000000E+03  T(175) =  .5000000E+03
   T(176) =  .5000000E+03  T(177) =  .5000000E+03  T(178) =  .5000000E+03  T(179) =  .5000000E+03  T(180) =  .5000000E+03
   T(181) =  .5000000E+03  T(182) =  .5000000E+03  T(183) =  .5000000E+03  T(184) =  .5000000E+03  T(185) =  .5000000E+03
   T(186) =  .5000000E+03  T(187) =  .5000000E+03  T(188) =  .5000000E+03  T(189) =  .5000000E+03  T(190) =  .5000000E+03
   T(191) =  .5000000E+03  T(192) =  .5000000E+03  T(193) =  .5000000E+03  T(194) =  .5000000E+03  T(195) =  .5000000E+03
   T(196) =  .5000000E+03  T(197) =  .5000000E+03  T(198) =  .5000000E+03  T(199) =  .5000000E+03  T(200) =  .5000000E+03
   T(201) =  .5000000E+03  T(202) =  .5000000E+03  T(203) =  .5000000E+03  T(204) =  .5000000E+03  T(205) =  .5000000E+03
   T(206) =  .5000000E+03  T(207) =  .5000000E+03  T(208) =  .5000000E+03  T(209) =  .5000000E+03  T(210) =  .5000000E+03
   T(211) =  .5000000E+03  T(212) =  .5000000E+03  T(213) =  .5000000E+03  T(214) =  .5000000E+03  T(215) =  .5000000E+03
   T(216) =  .5000000E+03  T(217) =  .5000000E+03  T(218) =  .5000000E+03  T(219) =  .5000000E+03  T(220) =  .5000000E+03
   T(221) =  .5000000E+03  T(222) =  .5000000E+03  T(223) =  .5000000E+03  T(224) =  .5000000E+03  T(225) =  .5000000E+03
```

Figure 5-9. Model 2B Output (Sheet 2 of 16)

ORIGINAL PAGE IS OF POOR QUALITY

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

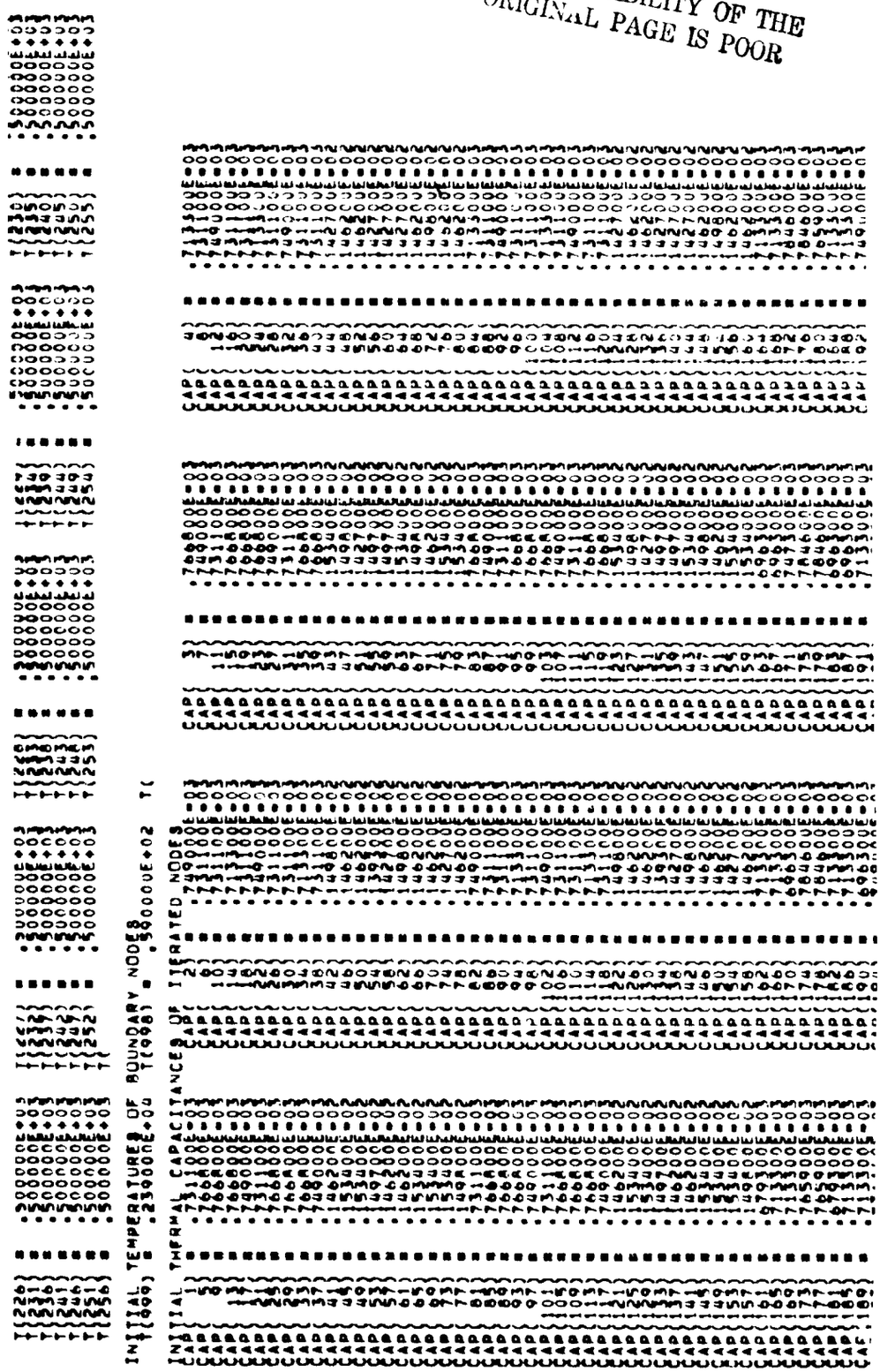


Figure 5-9. Model 2B Output (Sheet 3 of 16)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

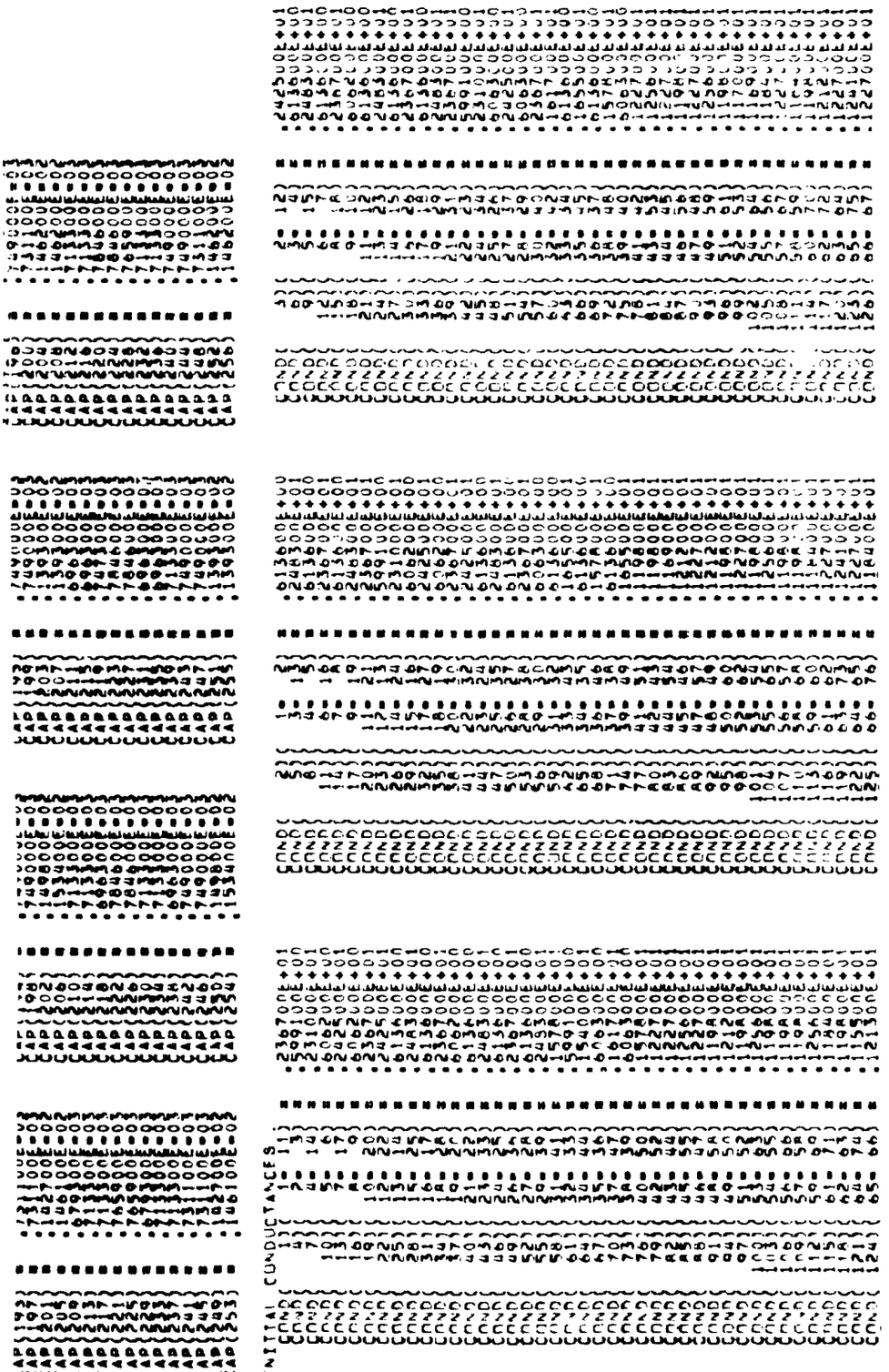


Figure 5-9. Model 2B Output (Sheet 4 of 16)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

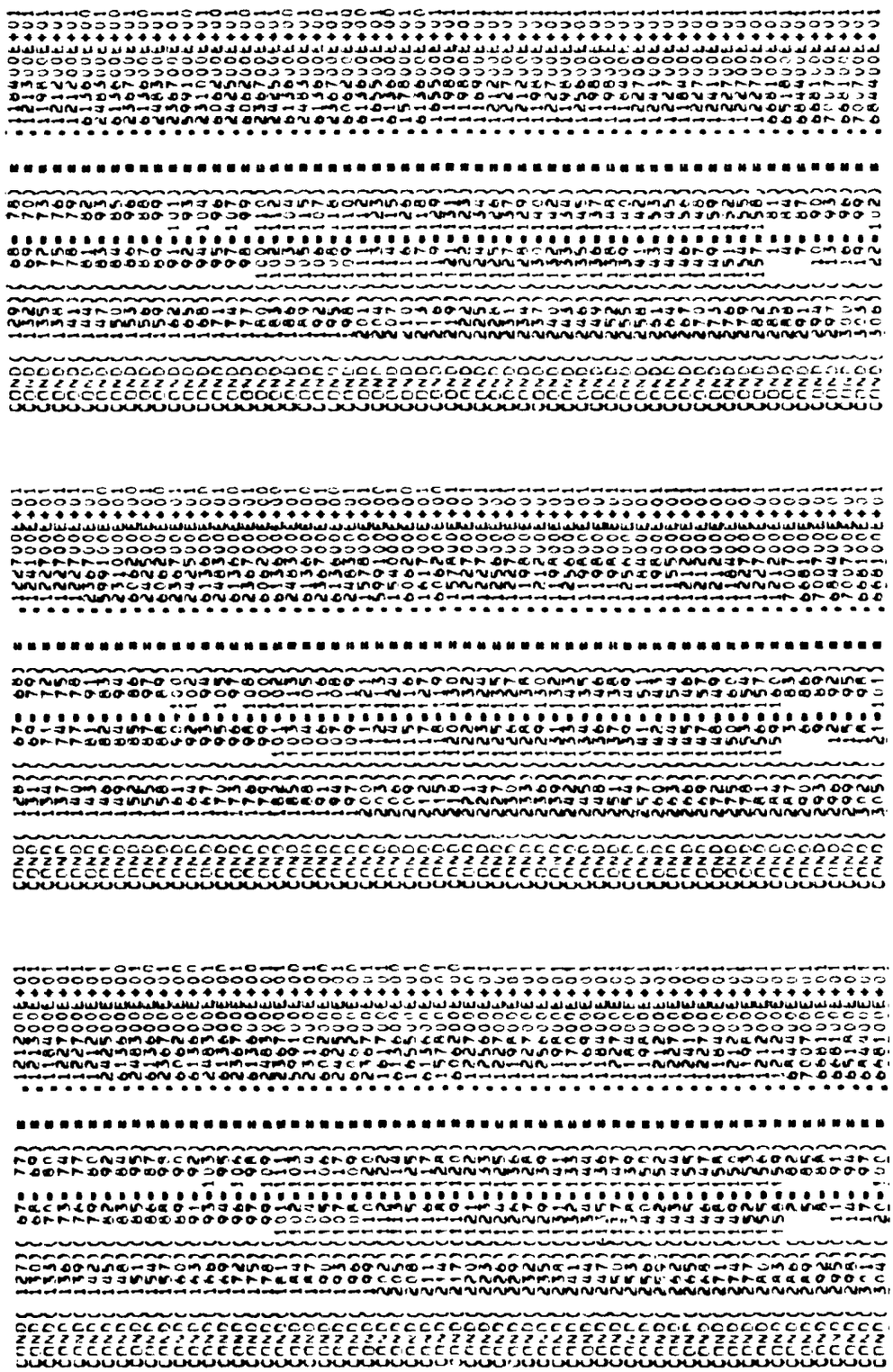


Figure 5-9. Model 2B Output (Sheet 5 of 16)

REPRODUCIBILITY OF THE
PAGE IS POOR

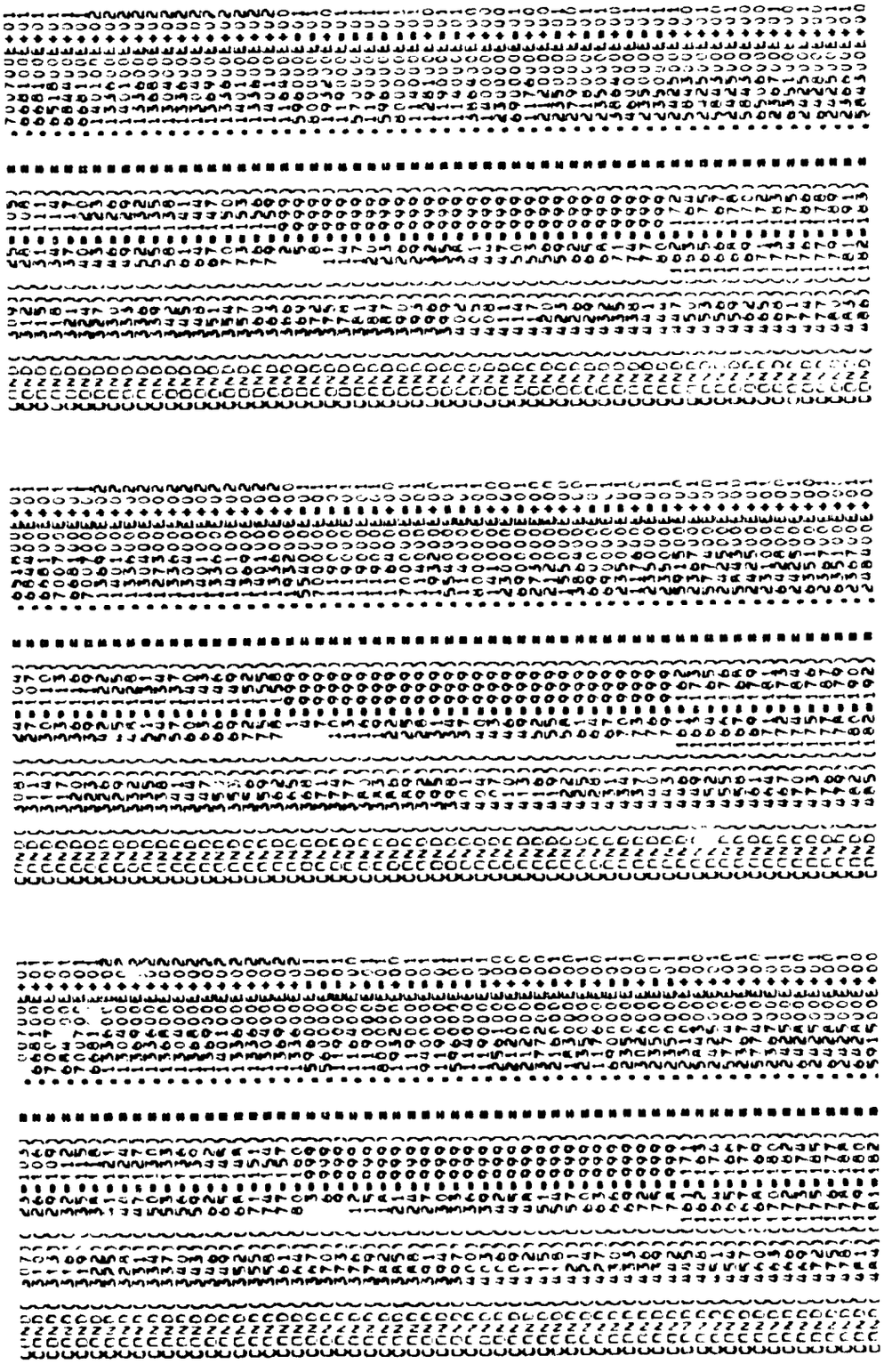


Figure 5-9. Model 2B Output (Sheet 6 of 16)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

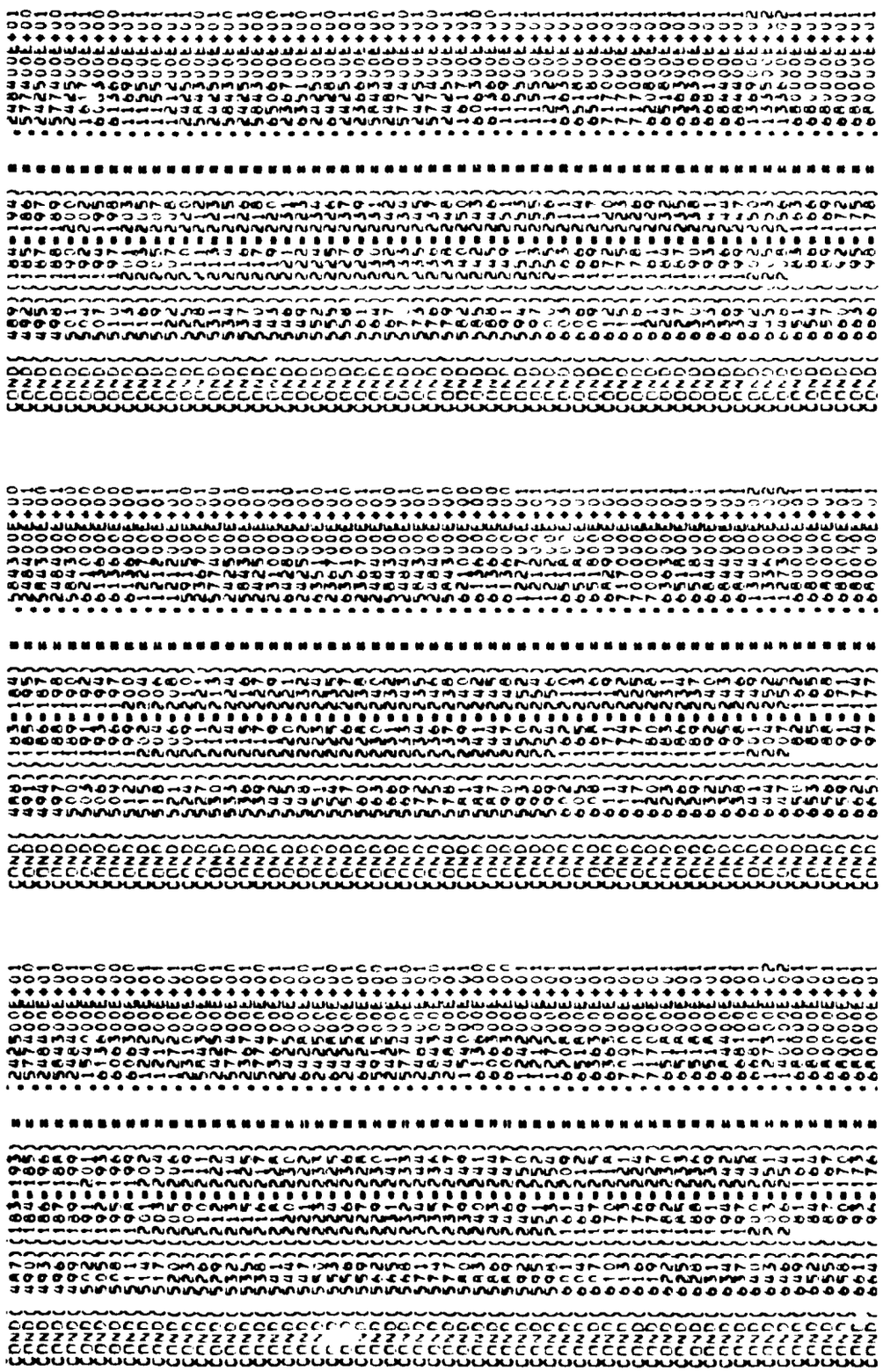


Figure 5-9. Model 2B Output (Sheet 7 of 16)

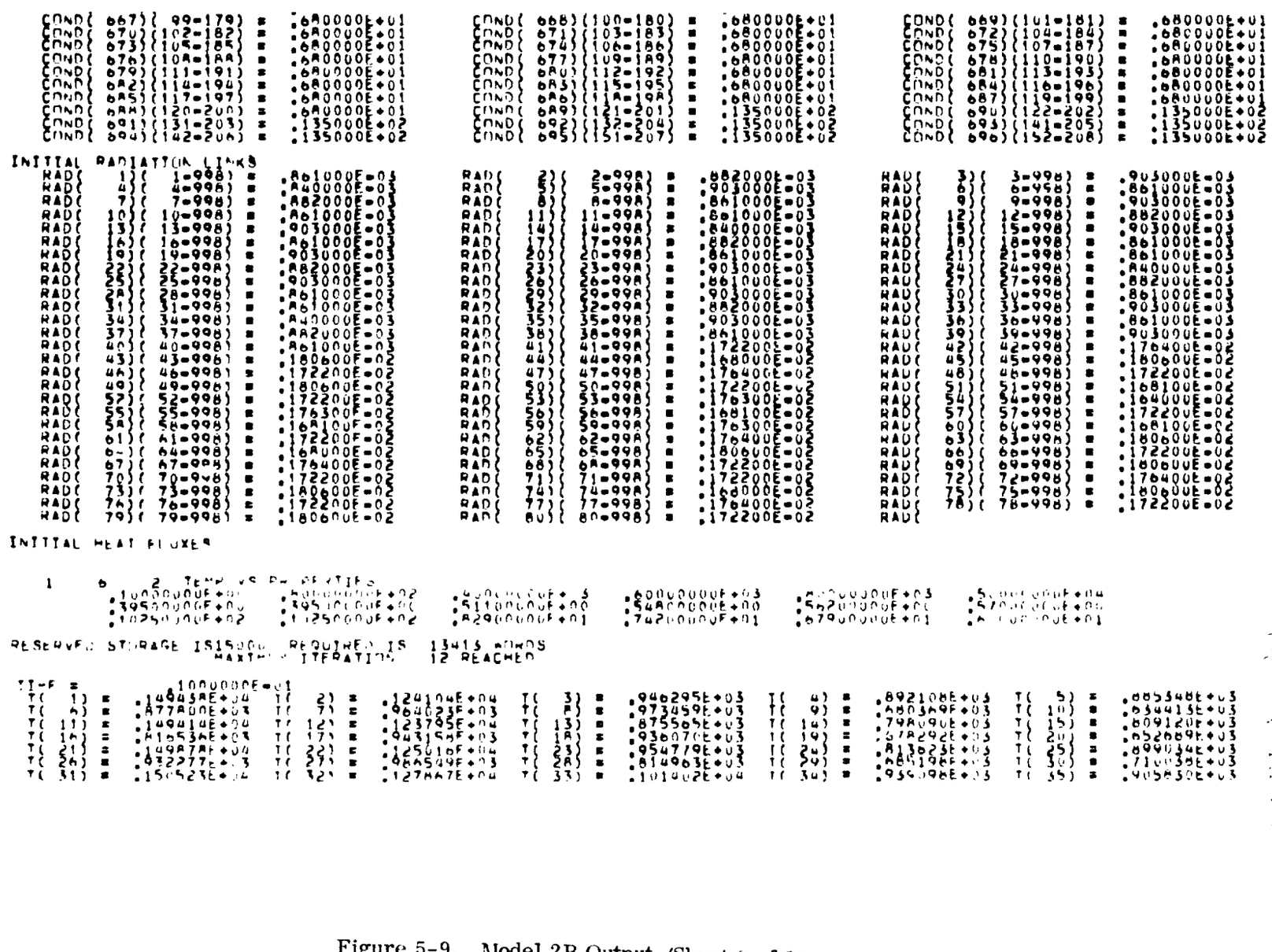


Figure 5-9. Model 2B Output (Sheet 8 of 16)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

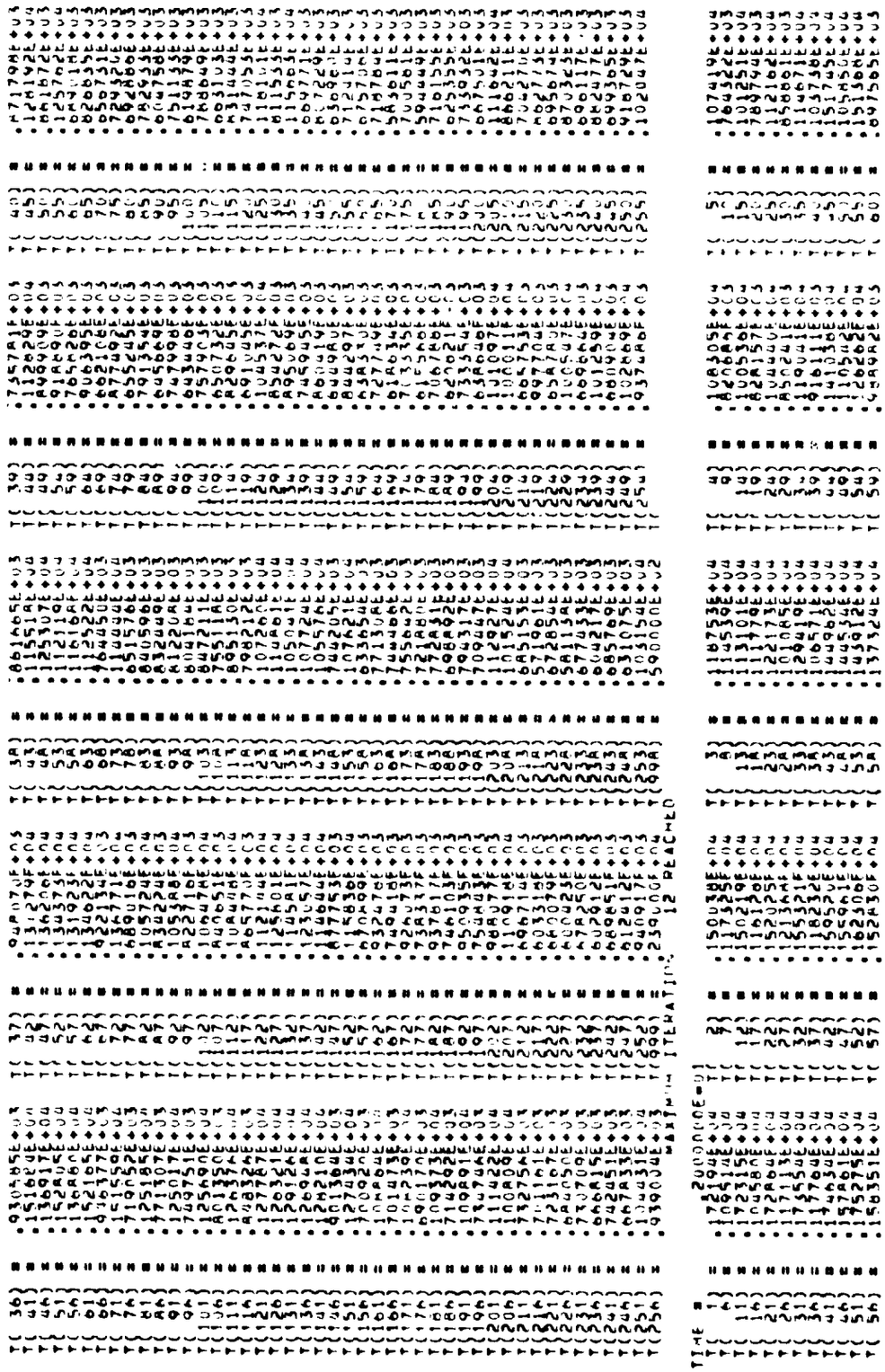


Figure 5-9. Model 2B Output (Sheet 9 of 16)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

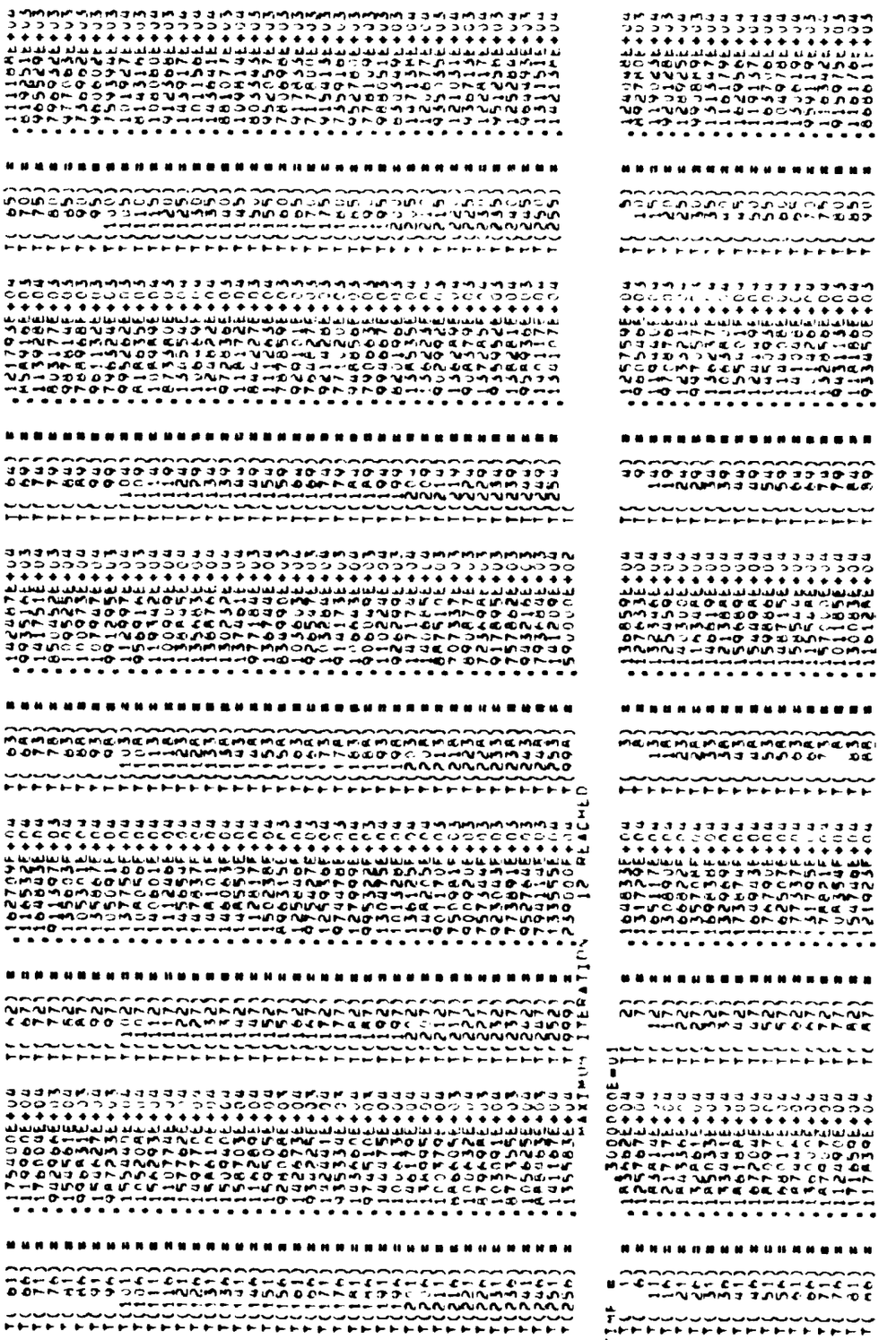


Figure 5-9. Model 2B Output (Sheet 10 of 16)

REPRODUCIBILITY OF THE
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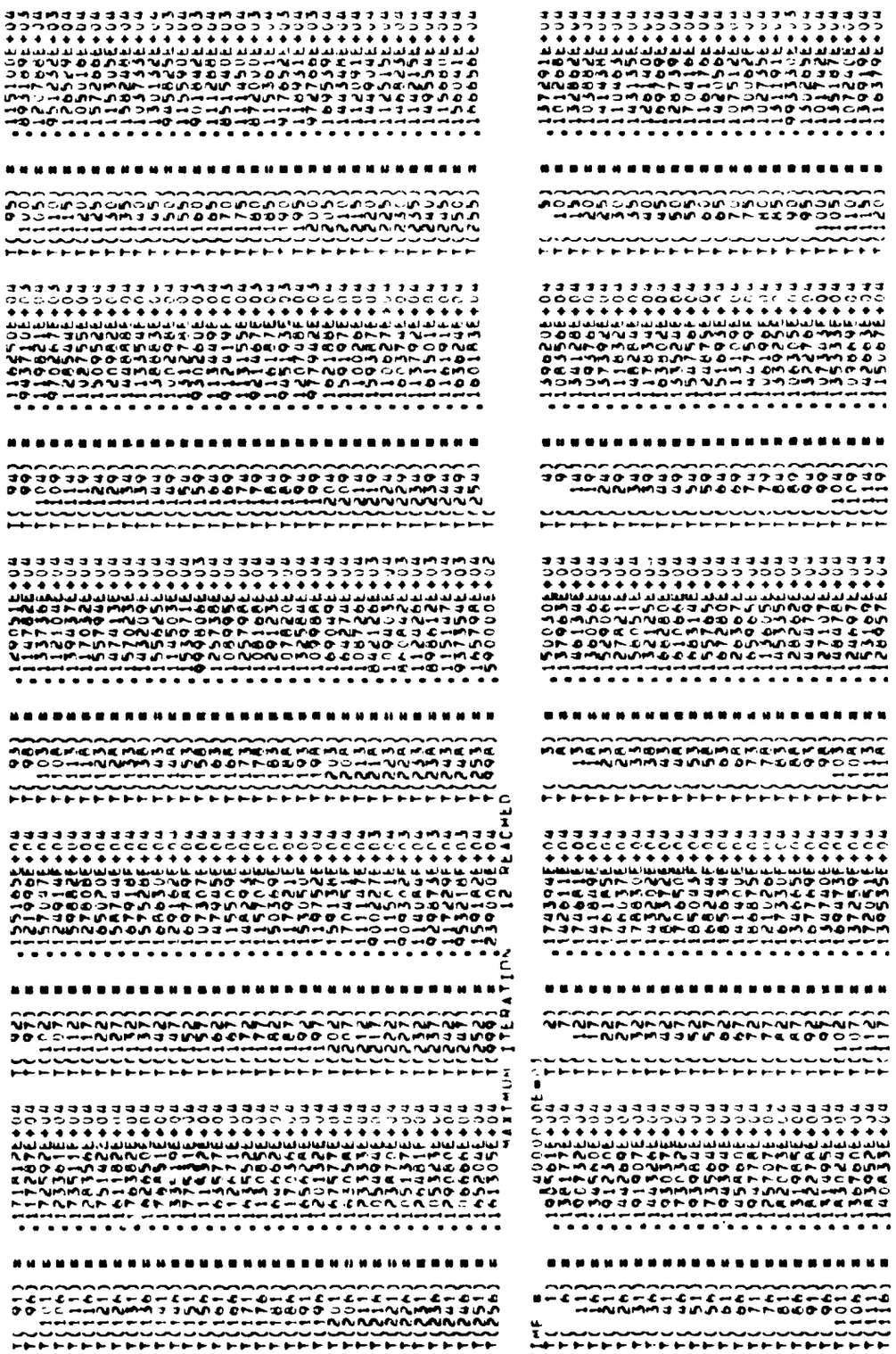


Figure 5-9. Model 2B Output (Sheet 11 of 16)

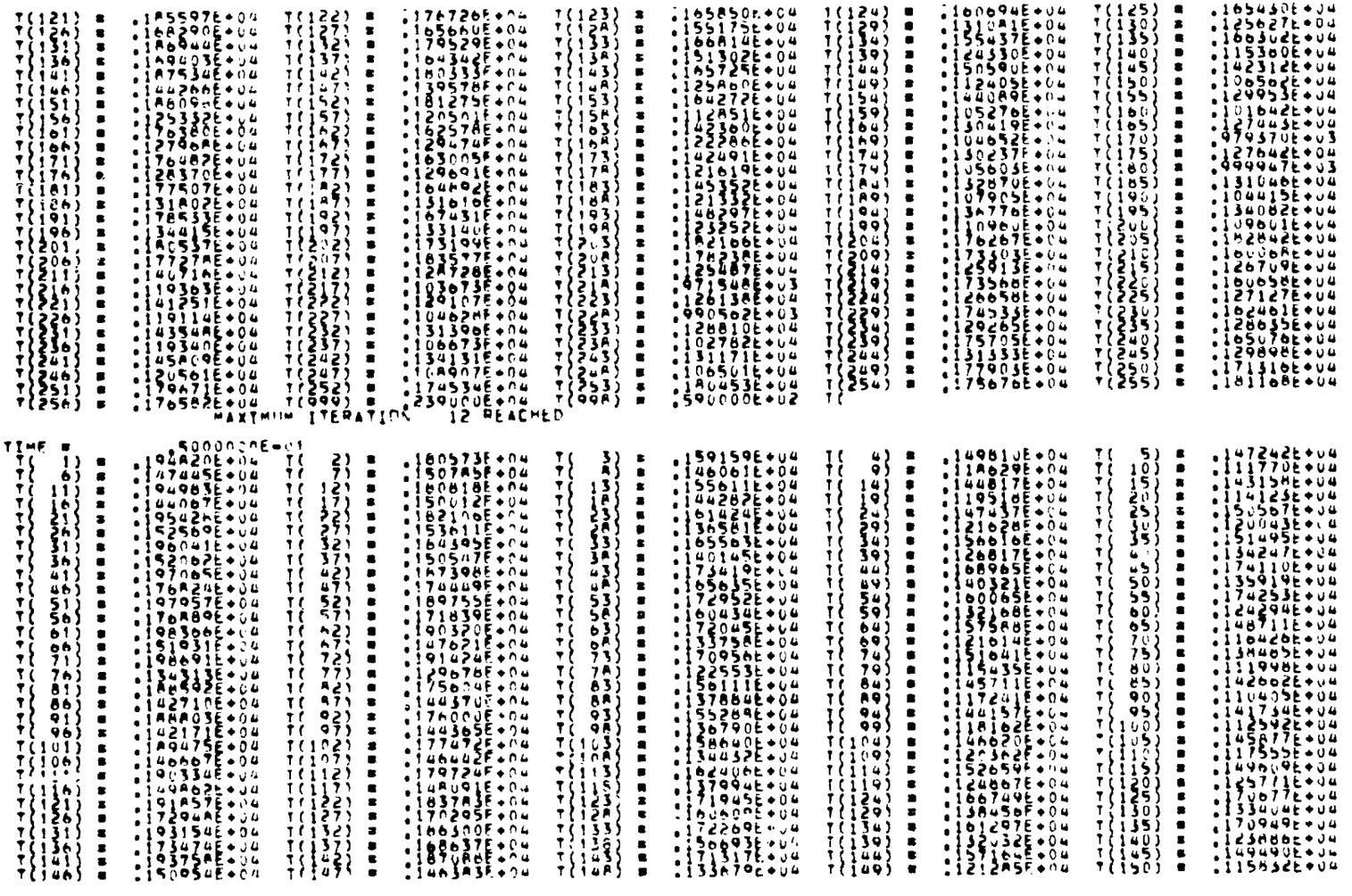


Figure 5-9. Model 2B Output (Sheet 12 of 16)

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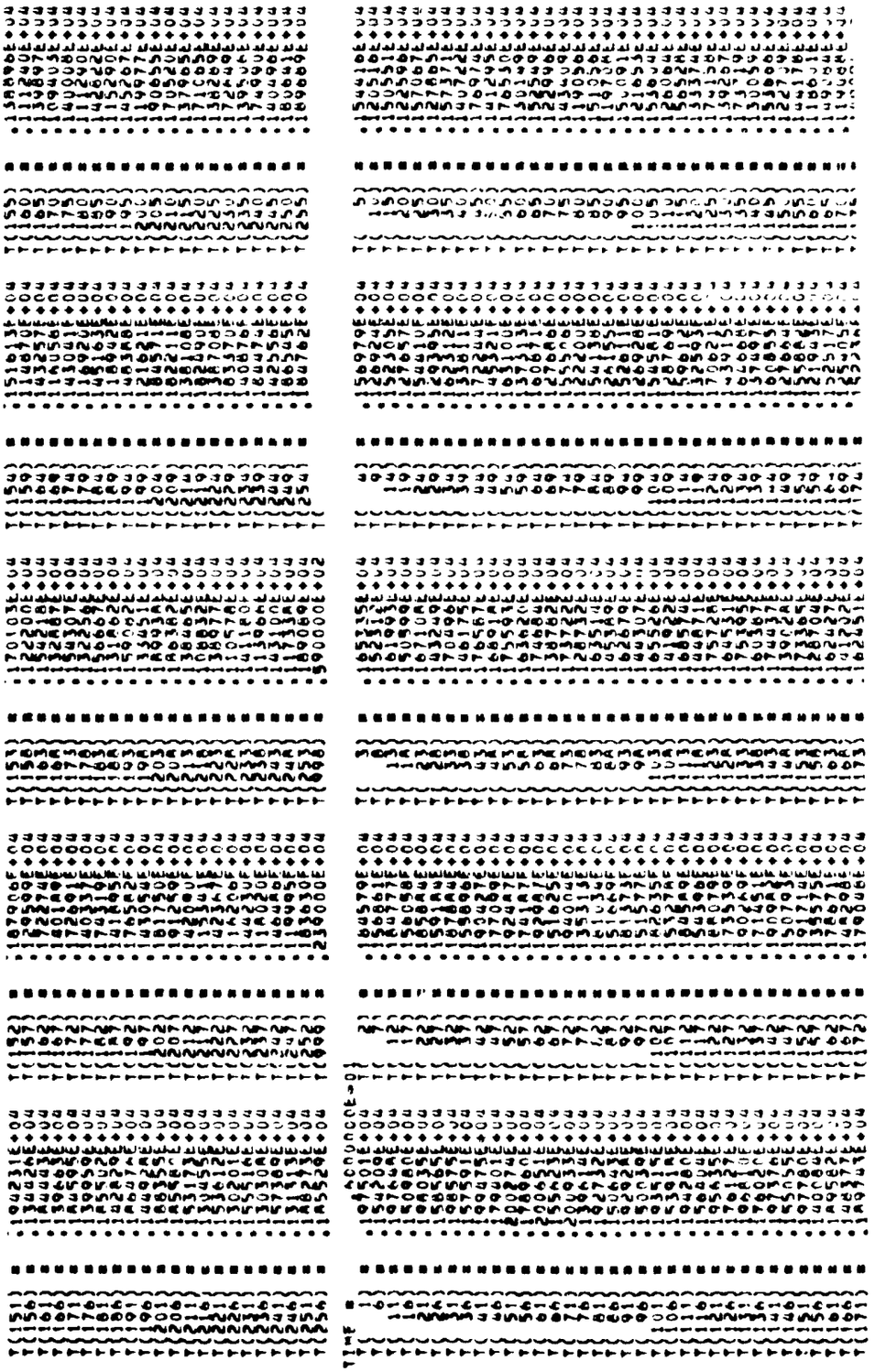


Figure 5-9. Model 2B Output (Sheet 13 of 16)

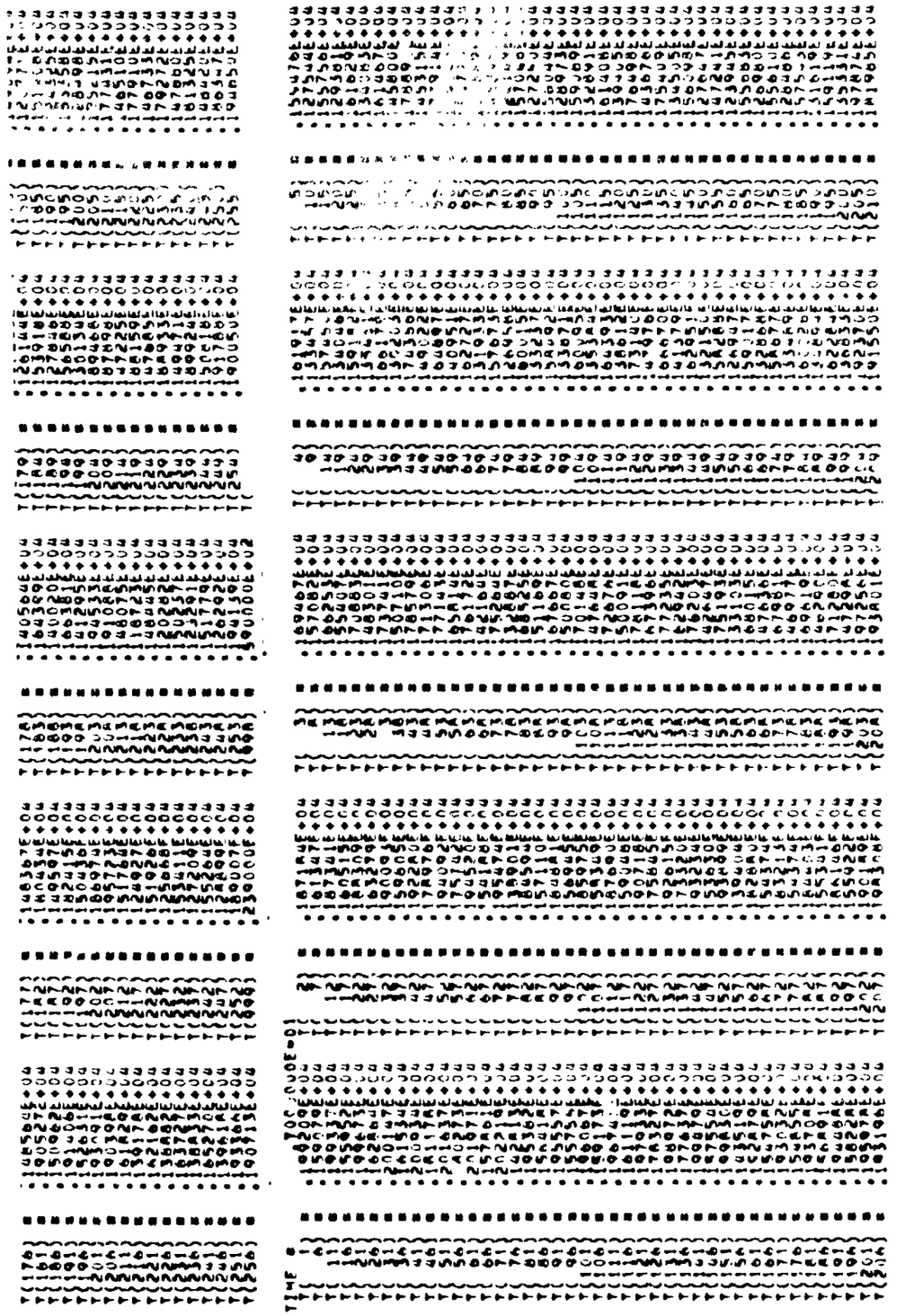


Figure 5-9. Model 2B Output (Sheet 14 of 16)

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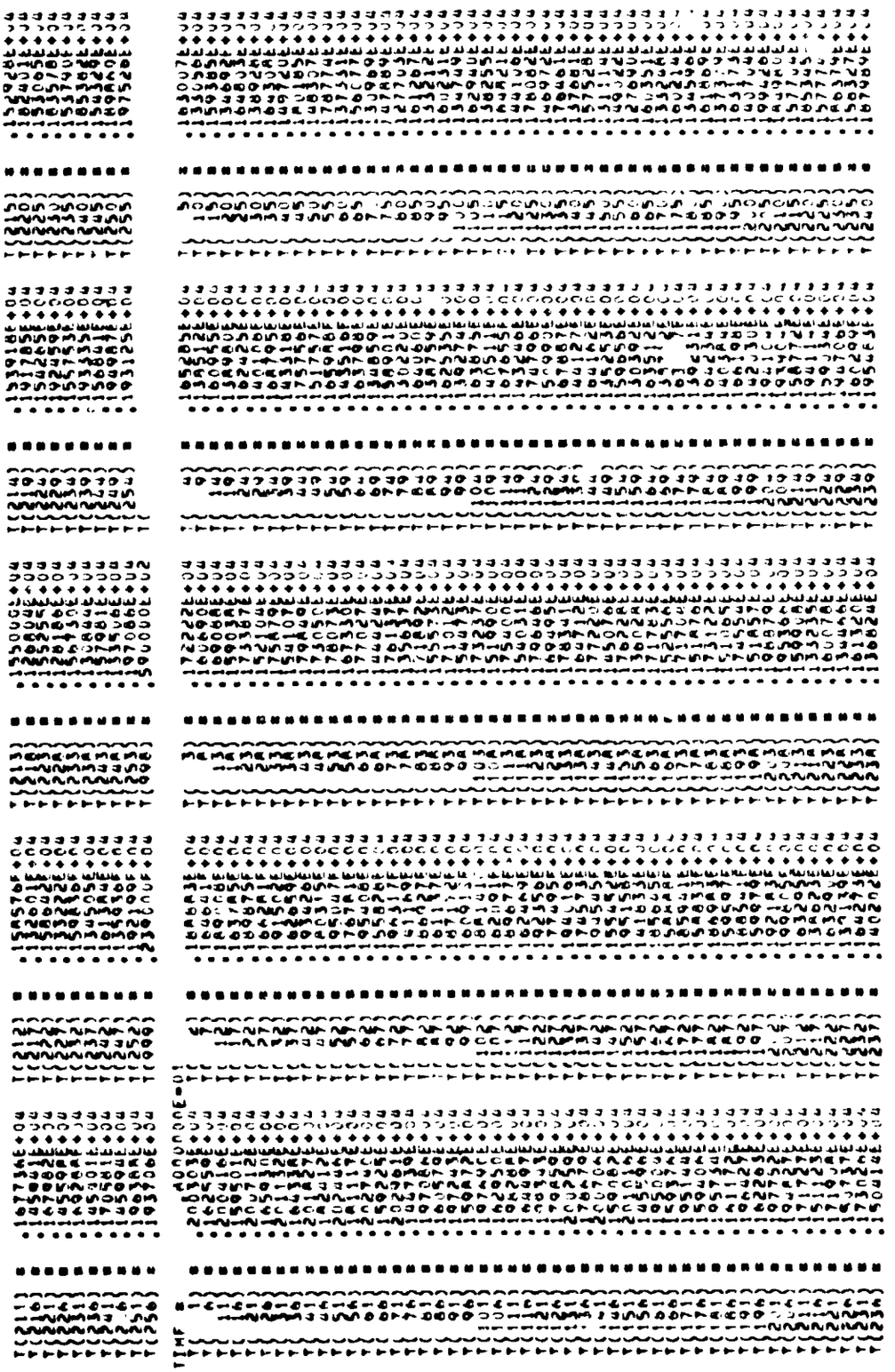


Figure 5-9. Model 2B Output (Sheet 15 of 16)

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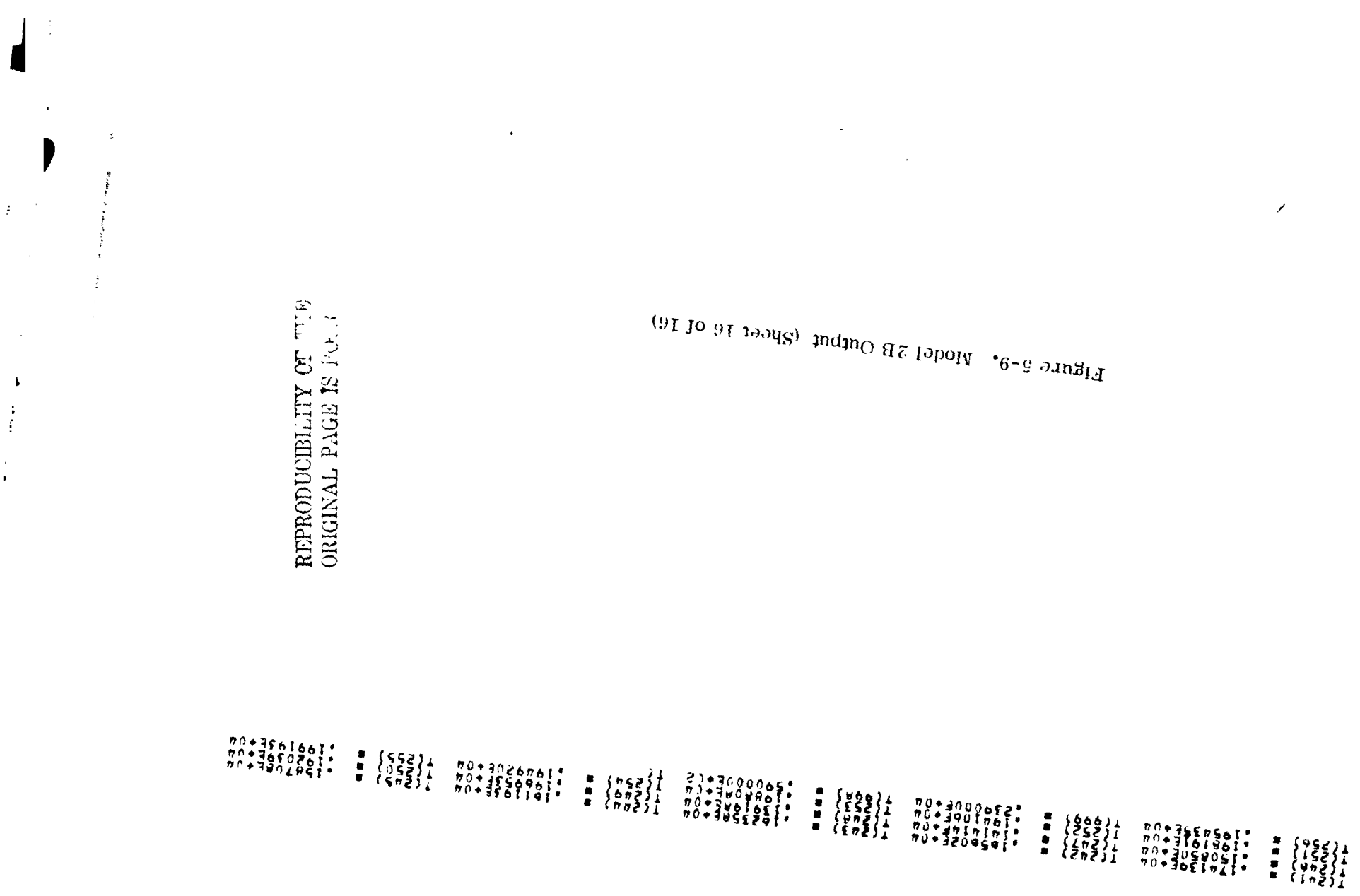


Figure 5-9. Model 2B Output (Sheet 16 of 16)

```
$STURE
 NUMBND  =  2,
 NUMITR  =  272,
 NUMCON  =  734,
 NUMTCN  =  1628,
 NUMNOD  =  1000,
 NUMFLX  =  0,
 NSTR    =  17000,
 NEVALU  =  14,
 NUMTOT  =  274,
 NUMSCR  =  2291,
 NUMRAD  =  80,
 SEND
 THIS ROU. REQUIRES A DATA AREA OF  45019 WORDS
          1         544         274         274         734
          0         274         274         80         3256        1468         274
        274         272         274         734         734         272          14          100
          1         545         274         1003        1827        734                     1000        0
       4720        5003        4119        5357        6613        3205         3809        2291        17000
      32272       32548       32818       33552       34286        6805         8899        3729
HIGHEST MEMORY IN HEXADECIMAL IS 00022330                                                   4729        4729
        274         272          14         734          80        1000            0        2291        17000
```

Figure 5-10. Model 2C Output (Sheet 1 of 16)

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Figure 5-10. Model 2C Output (Sheet 2 of 16)

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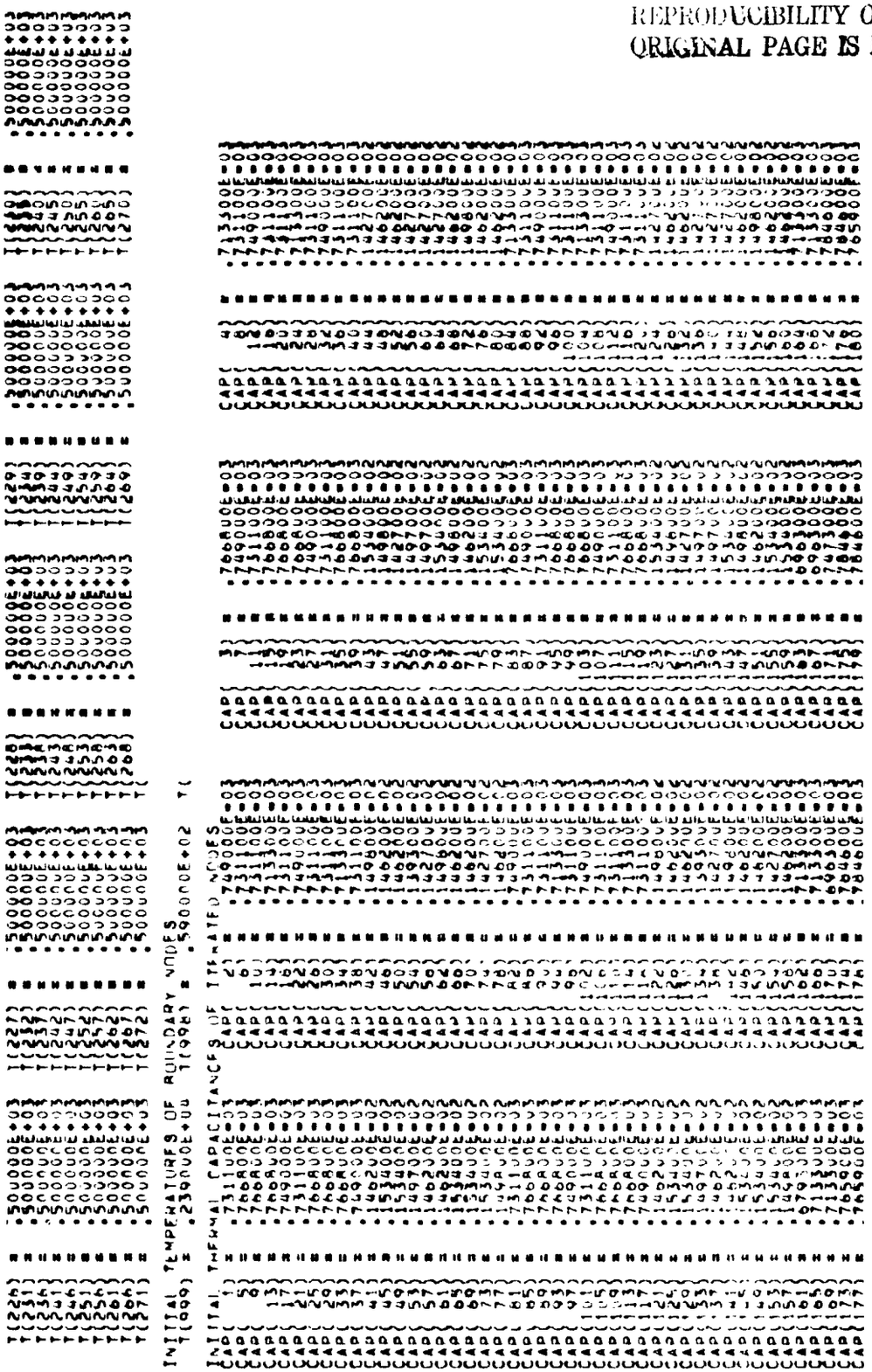


Figure 5-10. Model 2C Output (Sheet 3 of 16)

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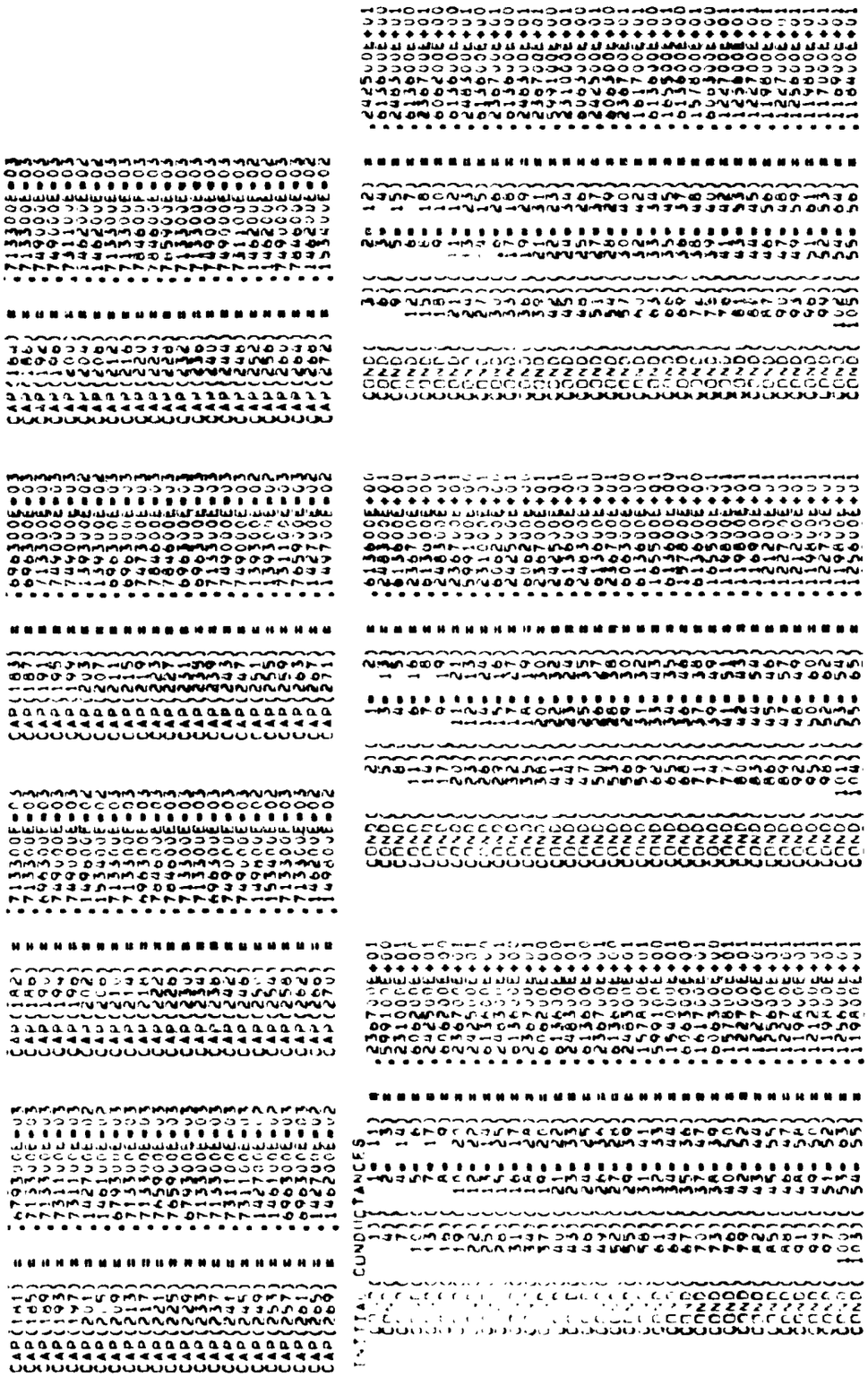


Figure 5-10. Model 2C Output (Sheet 4 of 16)

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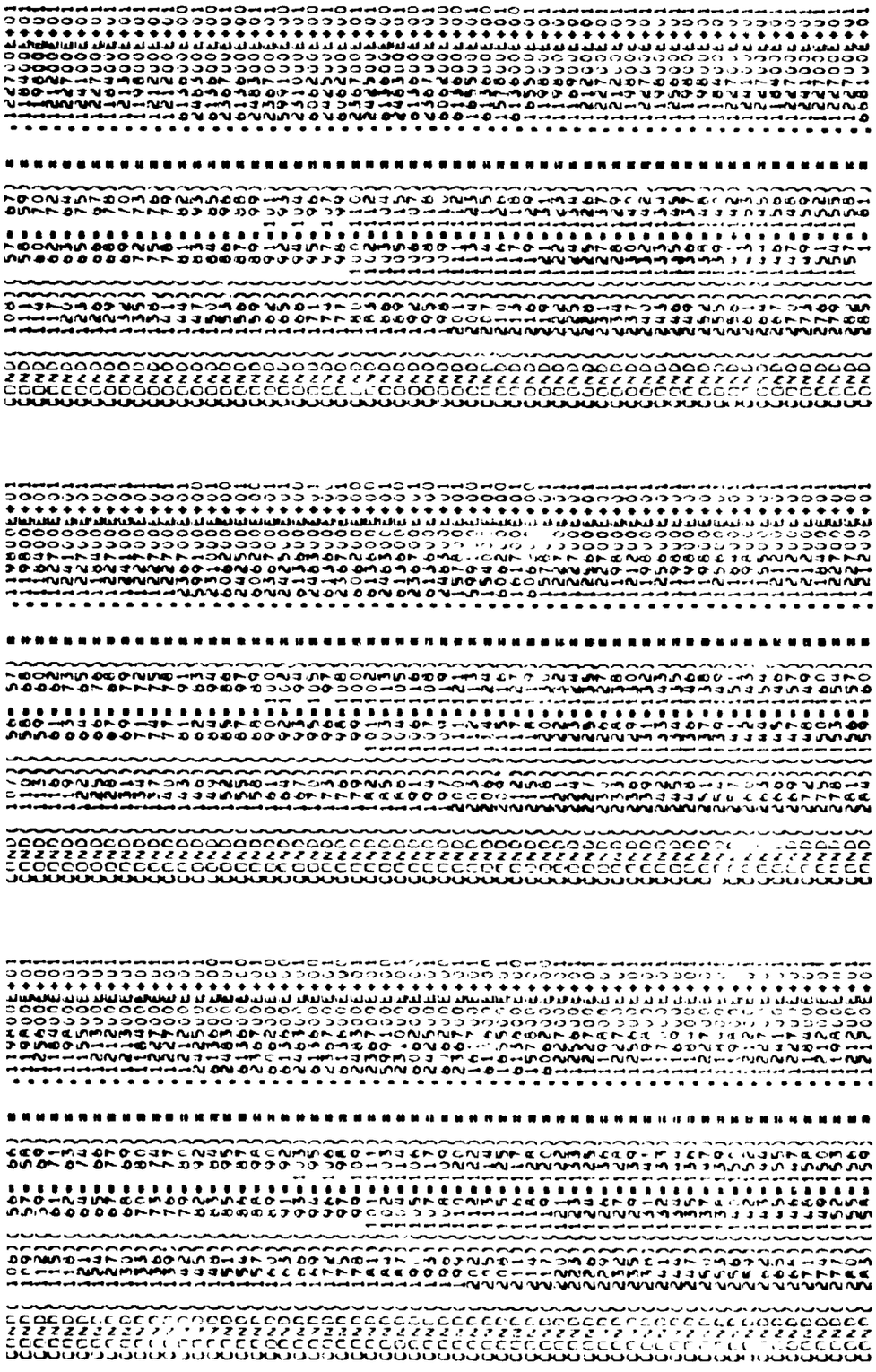


Figure 5-10. Model 2C Output (Sheet 5 of 16)

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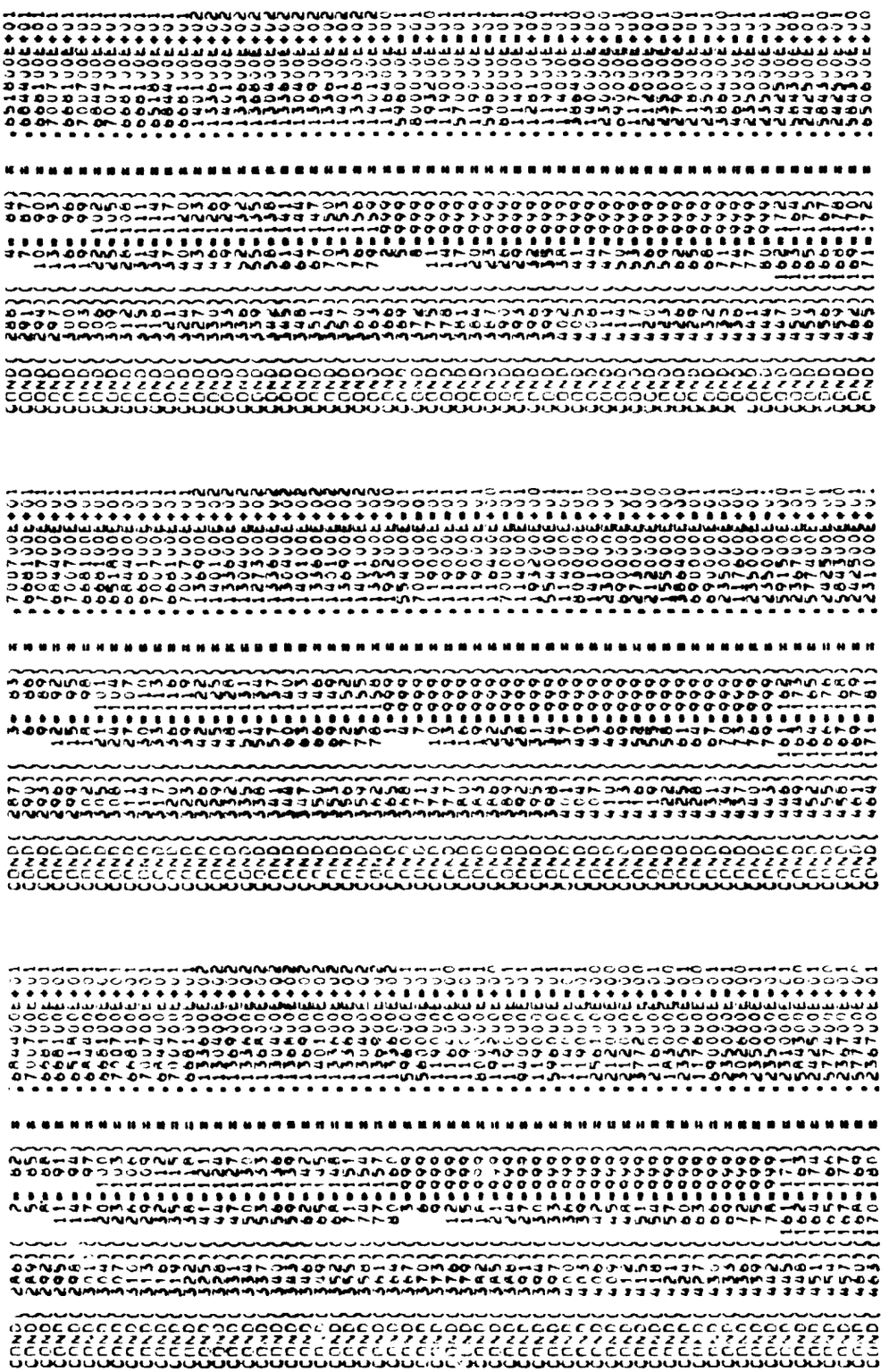


Figure 5-10. Model 2C Output (Sheet 6 of 16)

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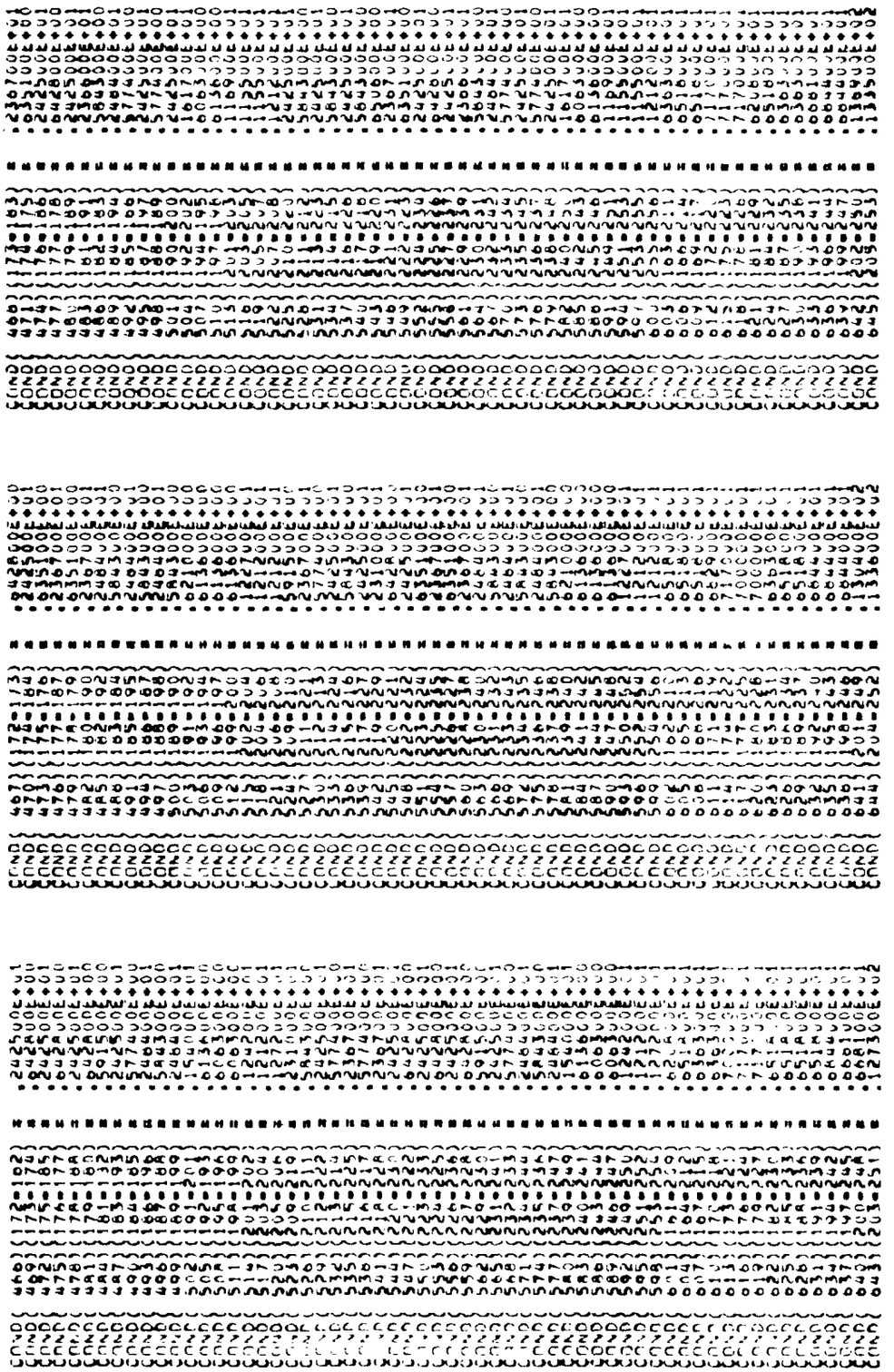


Figure 5-10. Model 2C Output (Sheet 7 of 16)

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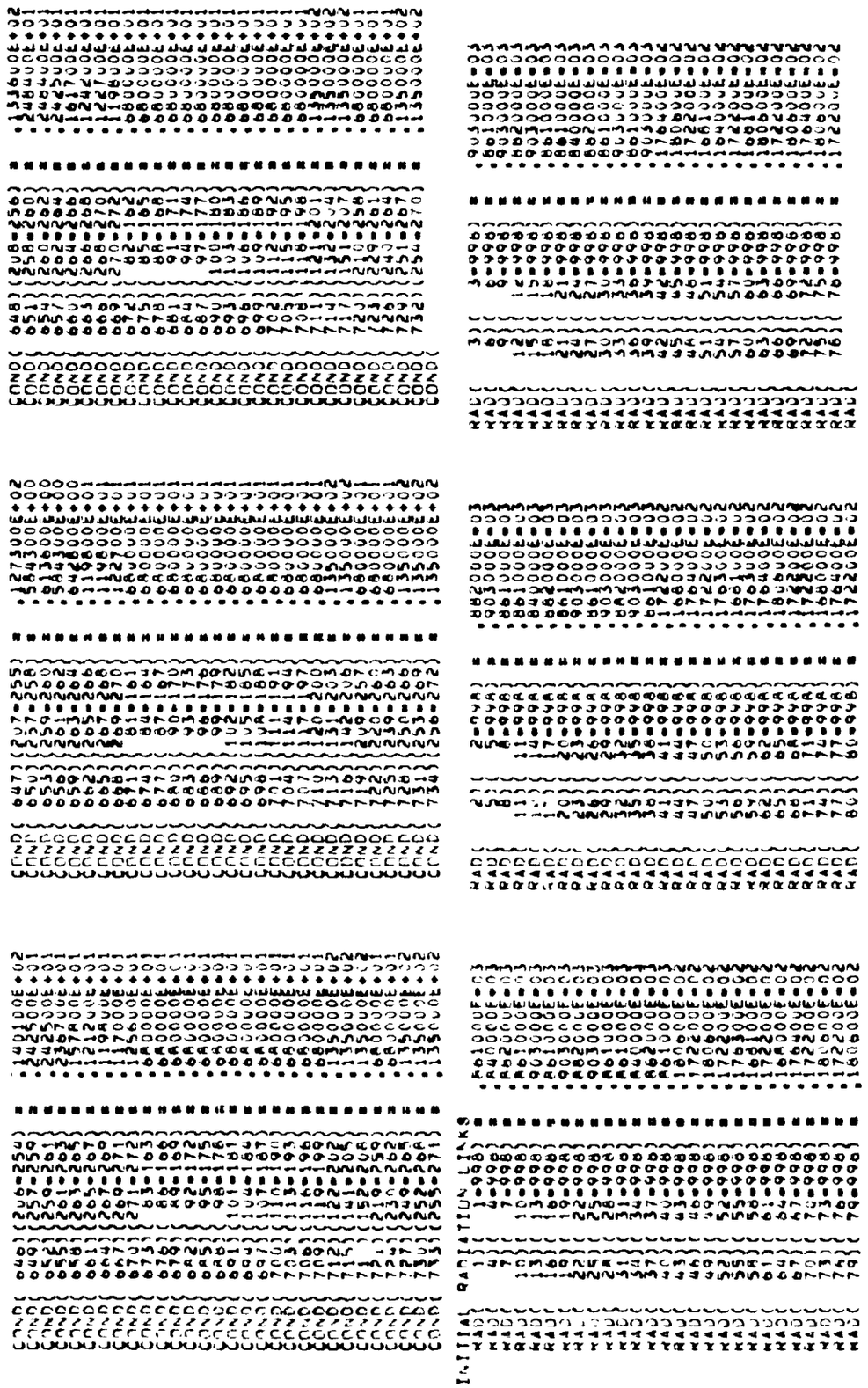


Figure 3-10. Model 2C Output (Sheet 5 of 16)

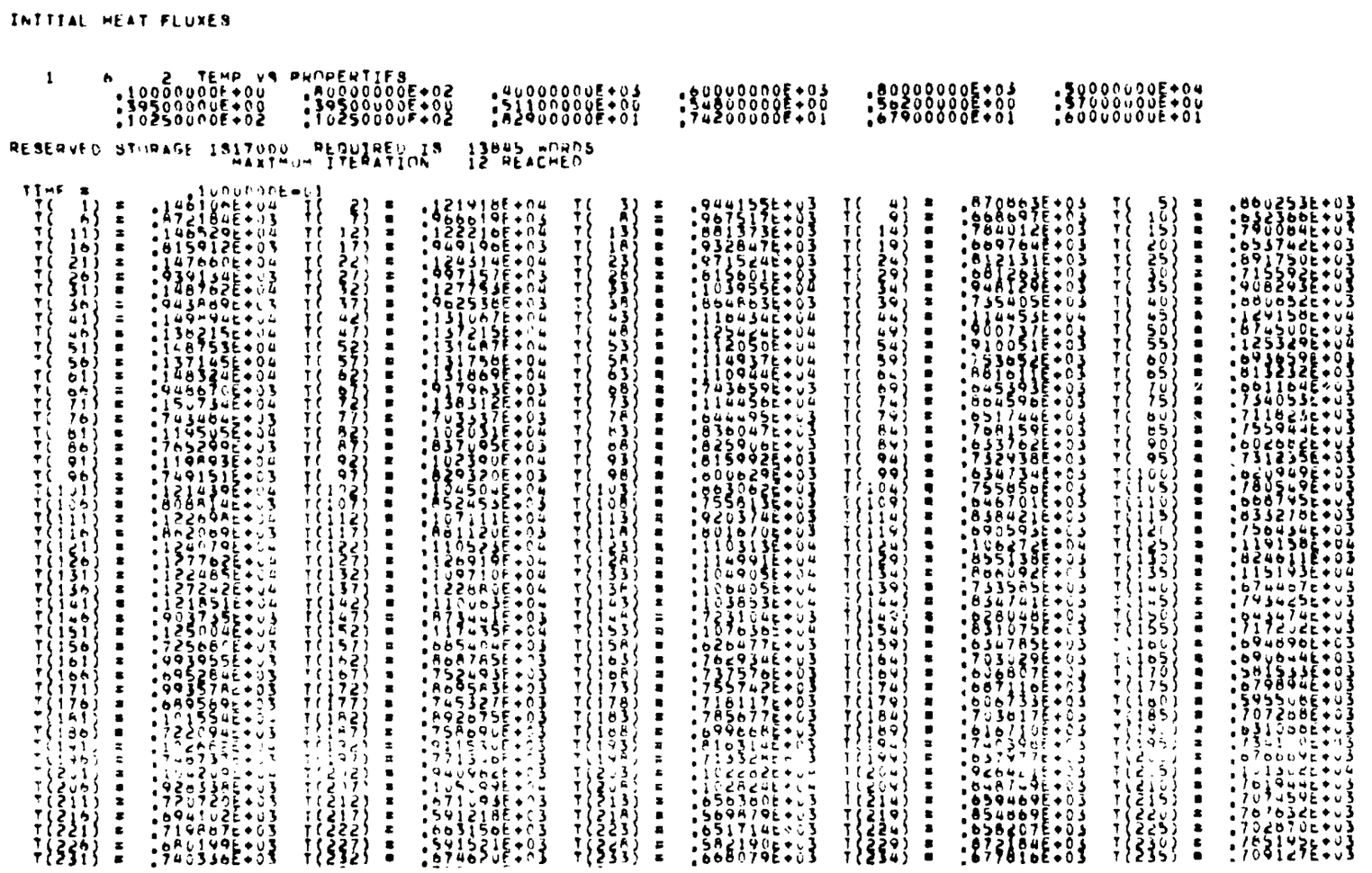


Figure 5-10. Model 2C Output (Sheet 9 of 16)

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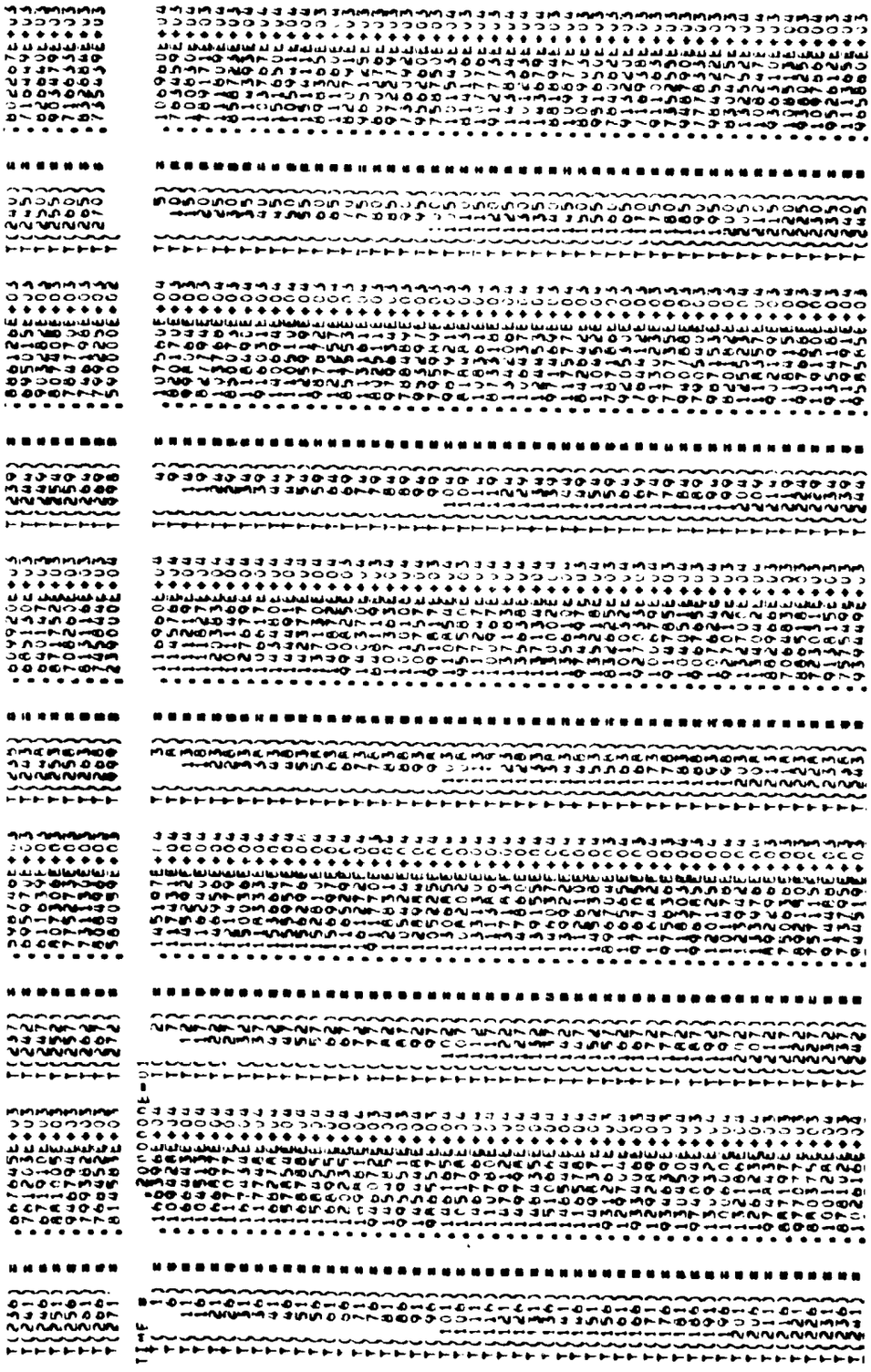


Figure 5-10. Model 2C Output (Sheet 10 of 16)

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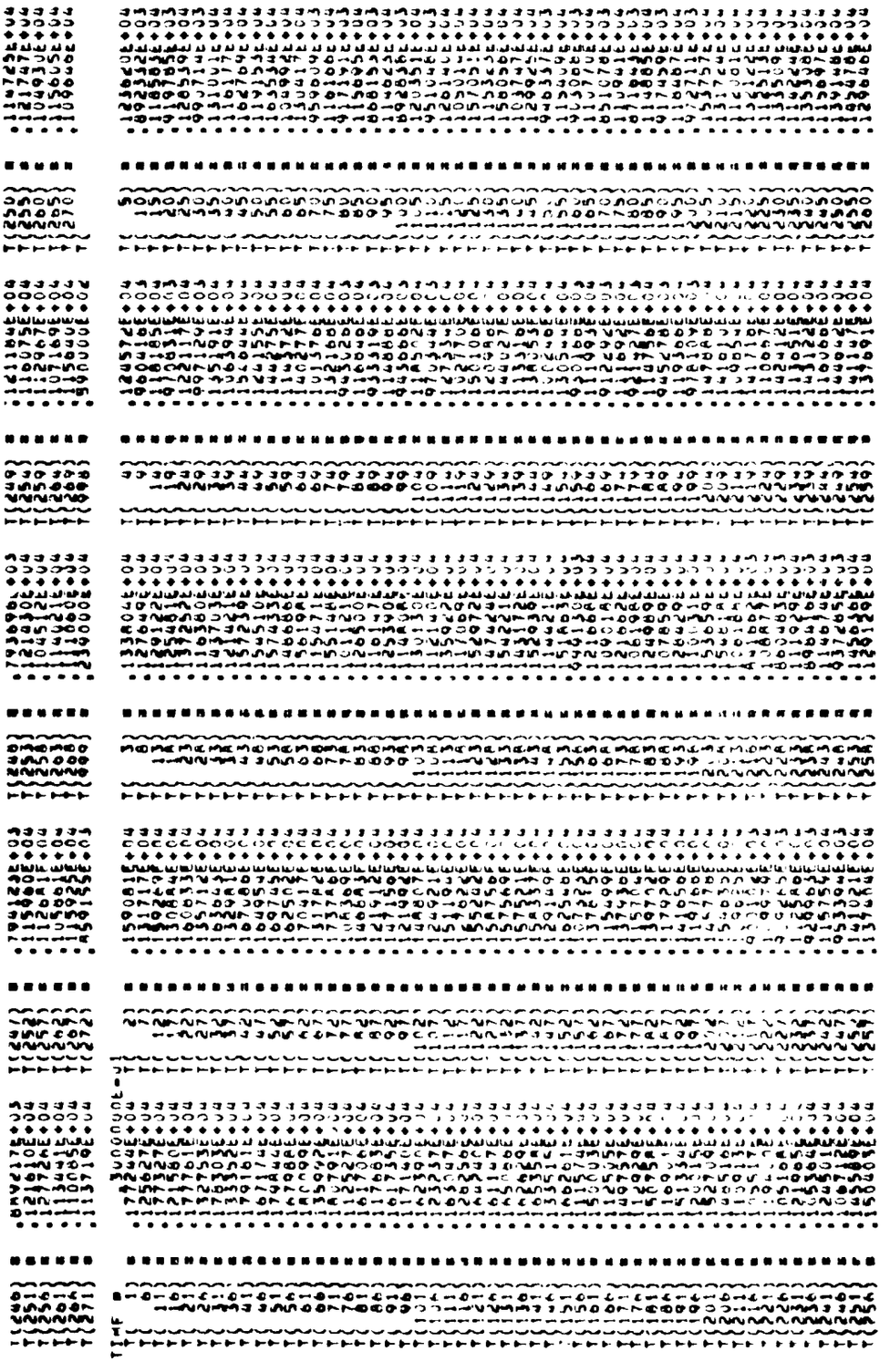


Figure 5-10. Model 2C Output (Sheet 11 of 16)

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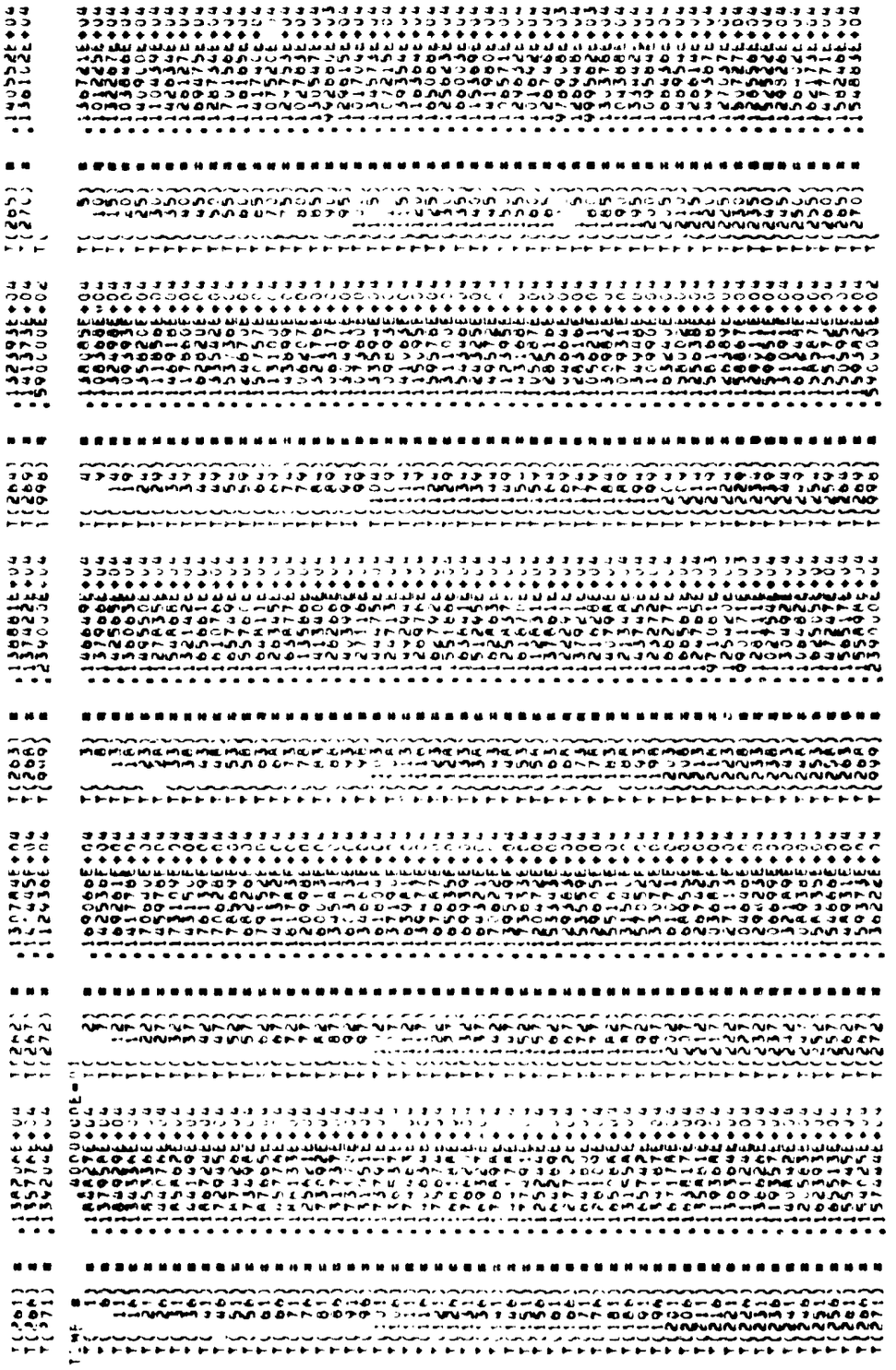


Figure 5-10. Model 2C Output (Sheet 12 of 16)

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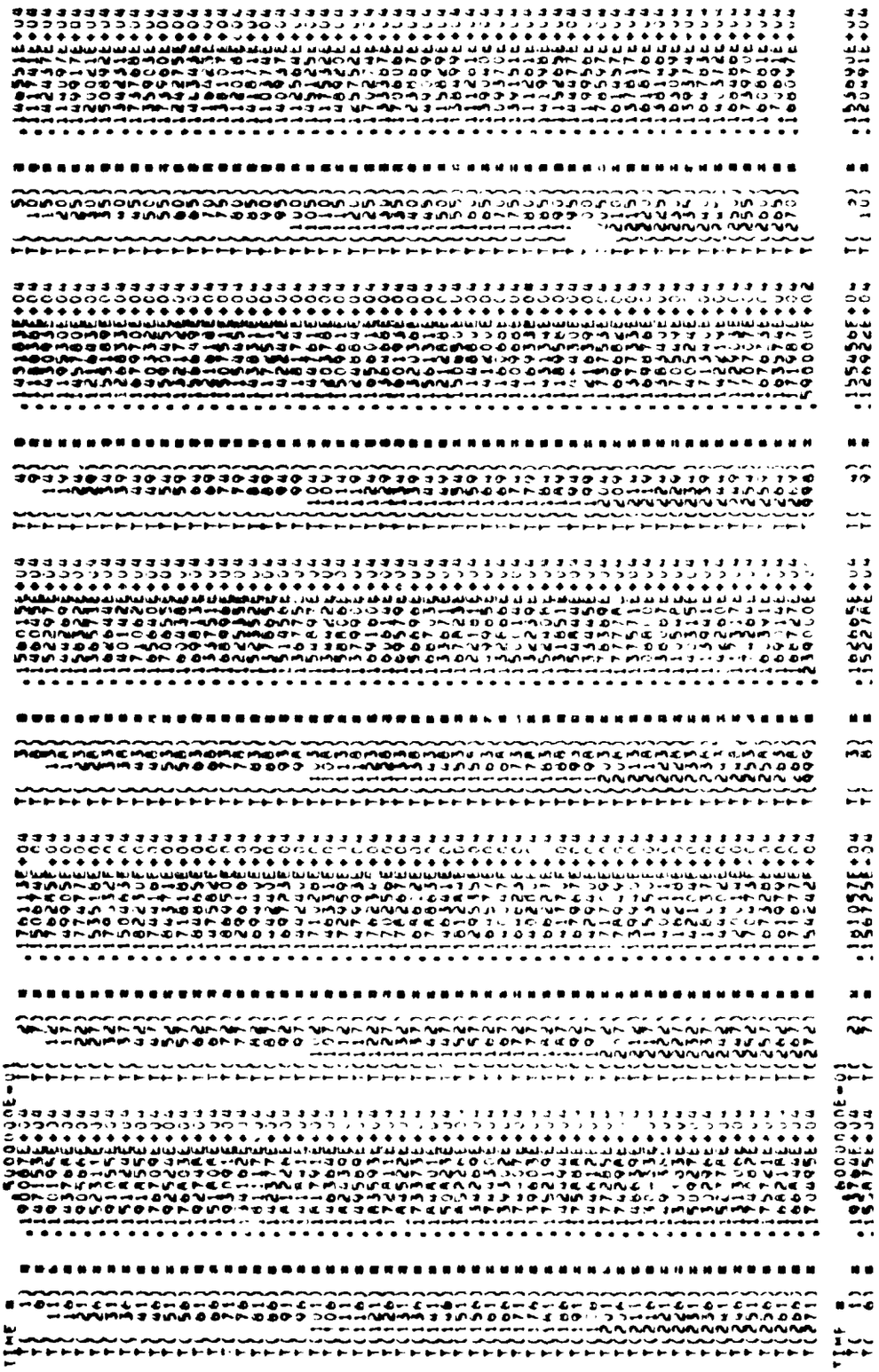


Figure 5-10. Model 2C Output (Sheet 13 of 16)

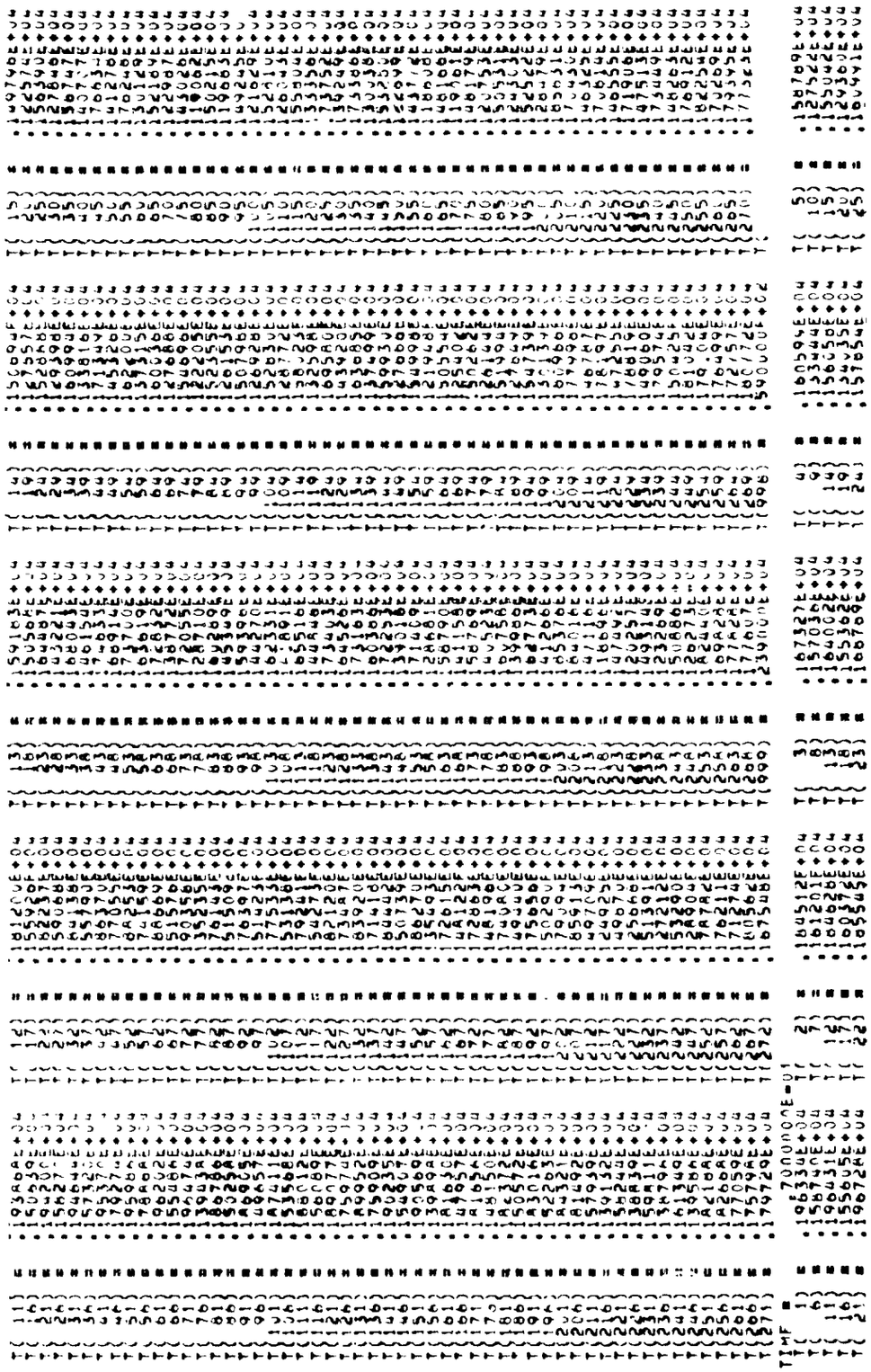


Figure 5-10. Model 2C Output (Sheet 14 of 16)

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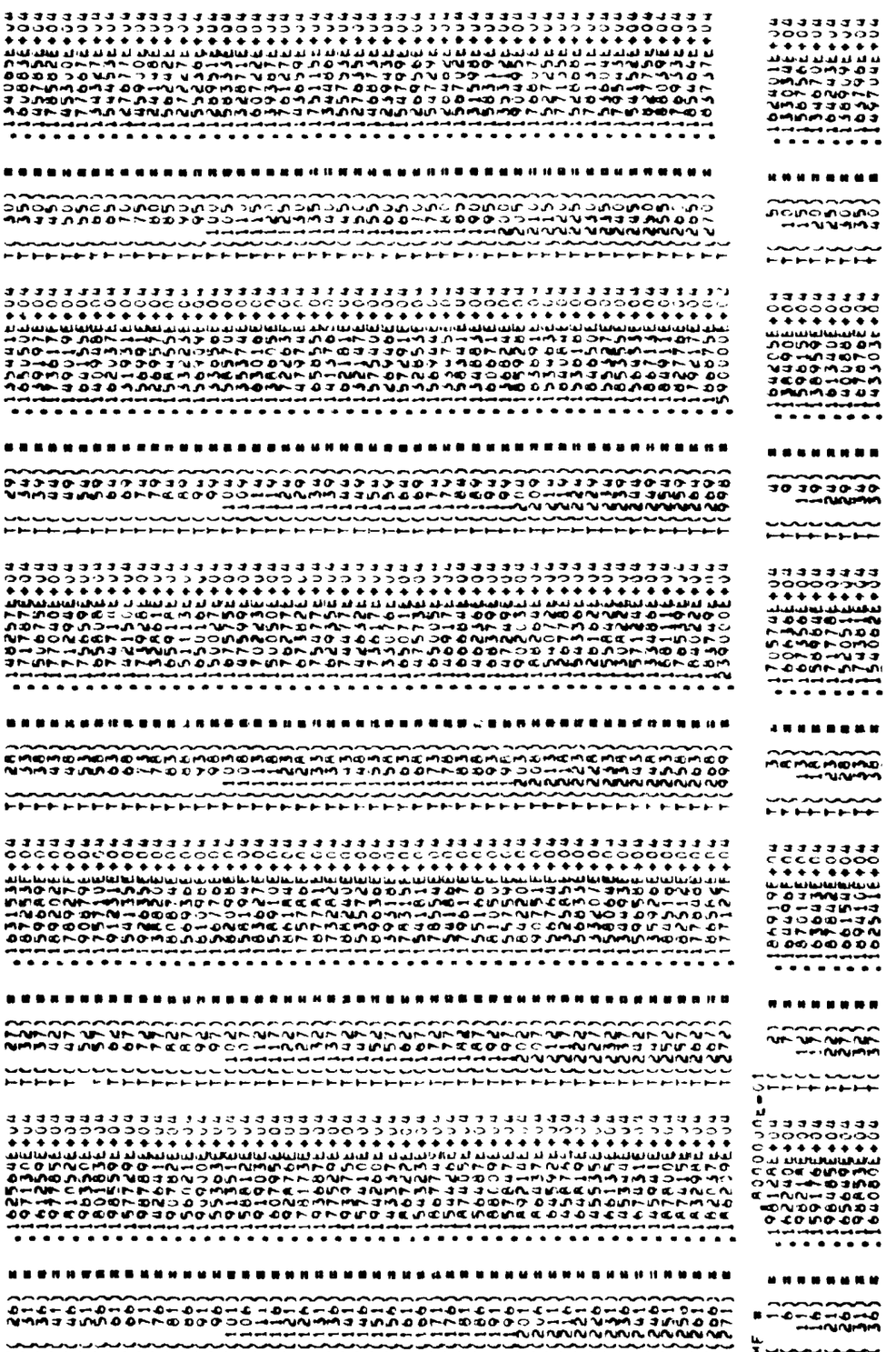


Figure 5-10. Model 2C Output (Sheet 15 of 16)

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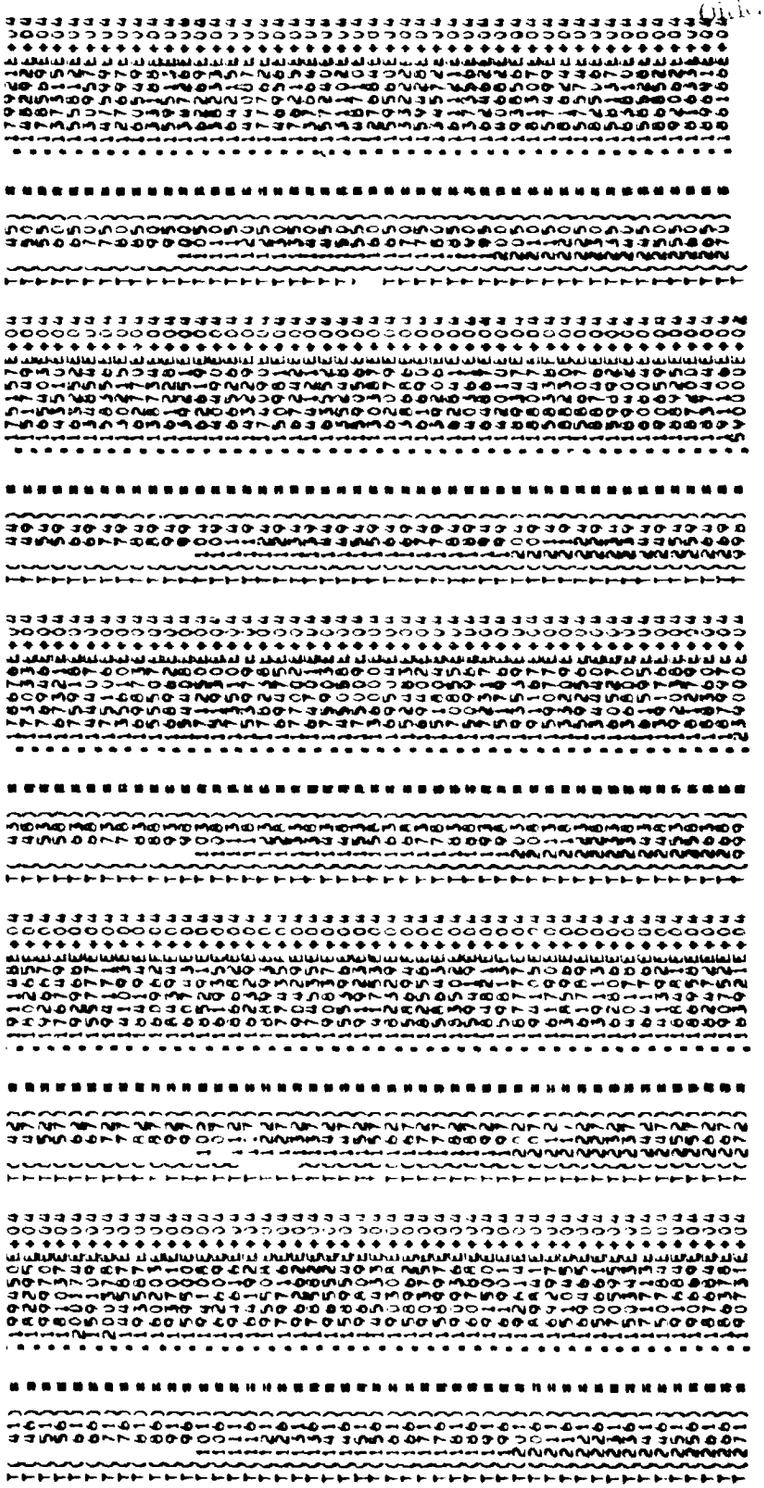


Figure 5-10. Model 2C Output (Sheet 16 of 16)

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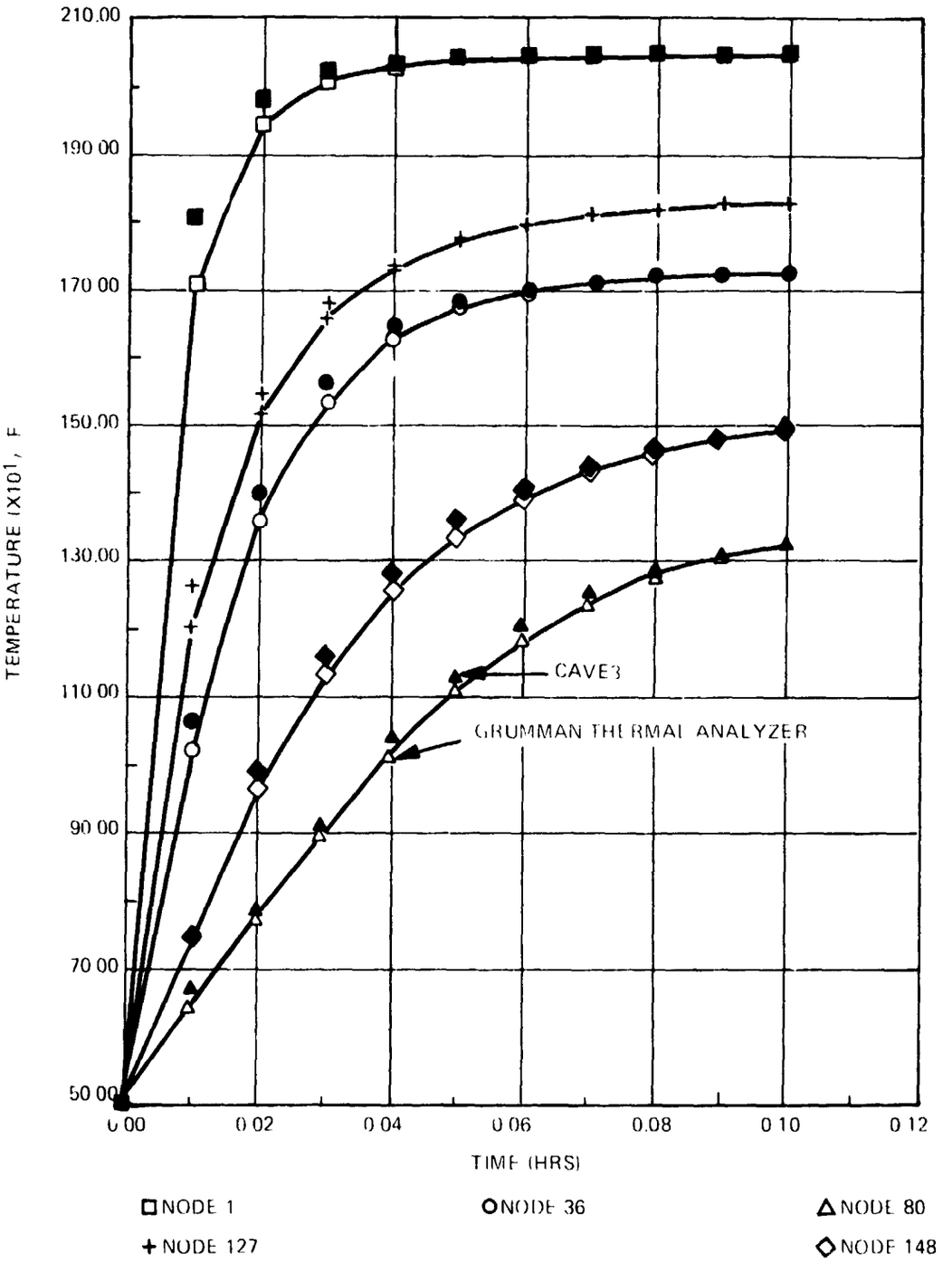
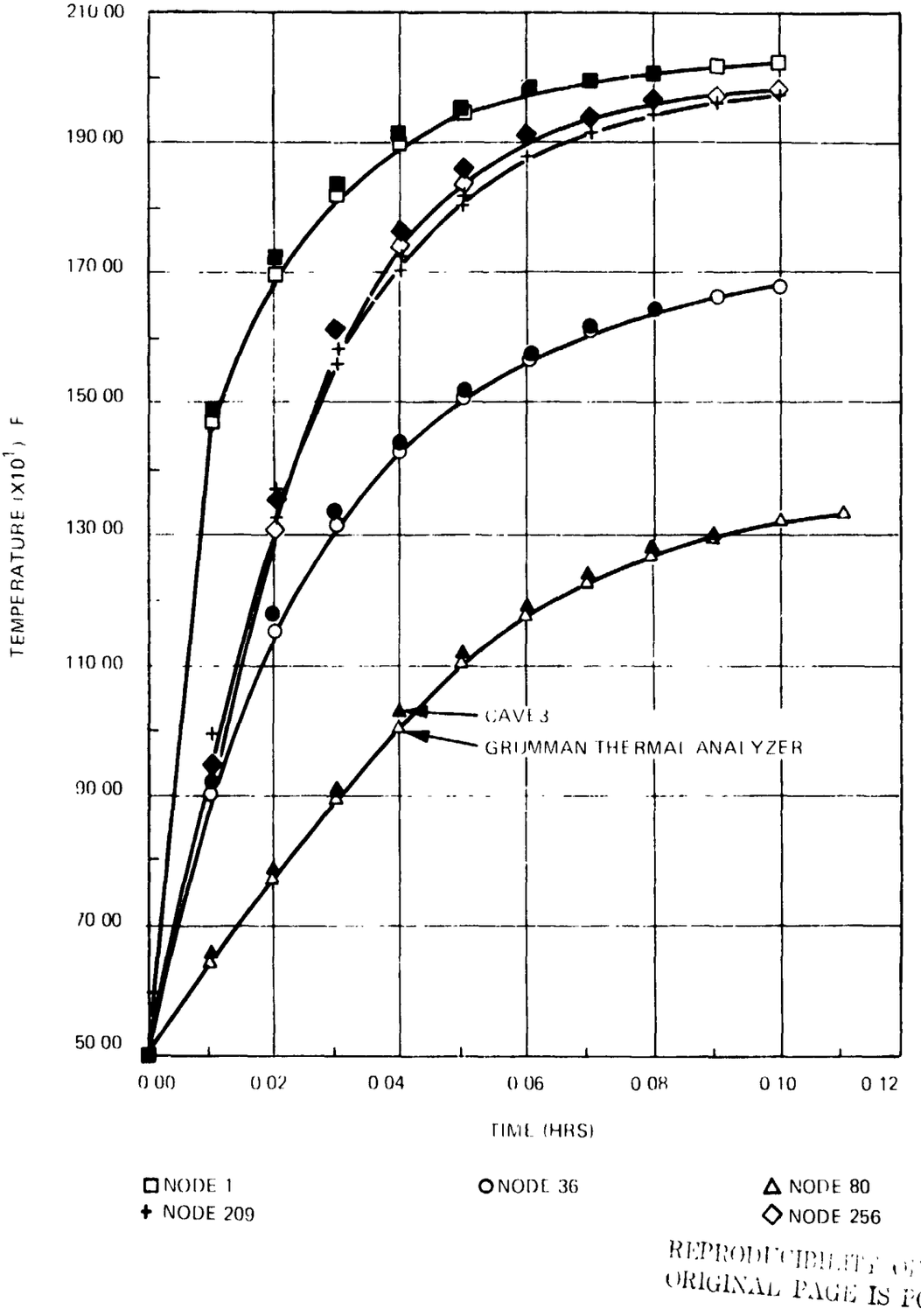


Figure 5-11. Sample Problem No. 2, Model 2A, Verification Plot



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Figure 5-12. Sample Problem No. 2, Model 2B, Verification Plot

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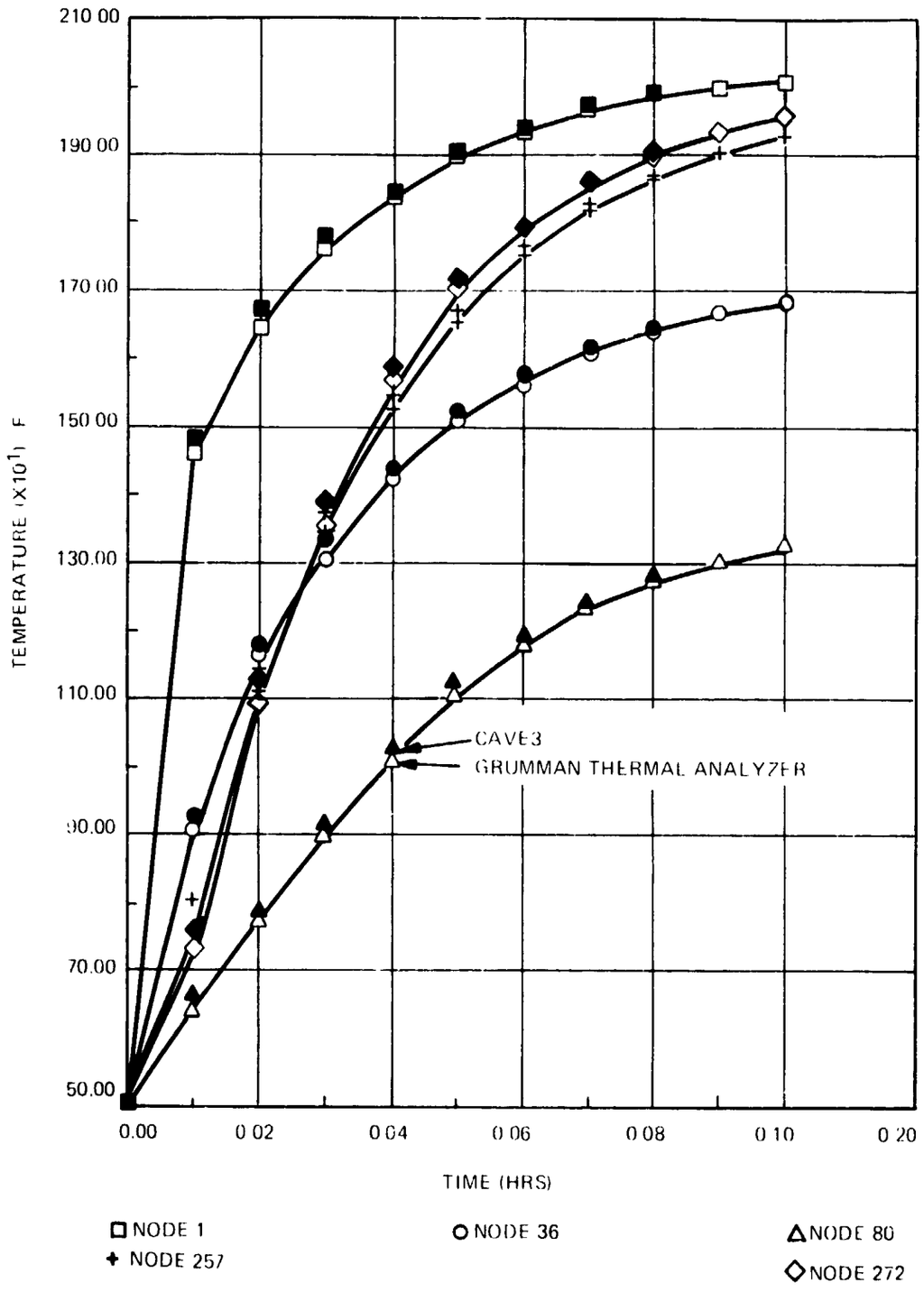


Figure 5-13. Sample Problem No. 2, Model 2C, Verification Plot

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Section 6

PROGRAMMER ORIENTED DOCUMENTATION

This section presents the details of the CAVE3 organization and structure. A simplified flow diagram of CAVE3 is presented in Figure 6-1.

CAVE3 is organized in a main program with 18 subroutines. The list of subroutines is given in Table 6-1 together with the function of each subroutine. Many subroutines are identical to subroutines used in the CAVE (Ref (1)) and CAPE codes (NASA CR-2435). Figure 6-2 presents the organization of CAVE3 in terms of the more important subroutine calls. Table 6-2 gives the variable list for CAVE3.

Flow charts or descriptions for each subroutine are given in Figures 6-3 through 6-19. They are arranged in alphabetical order. For convenience and completeness, they are given for subroutines that are identical to the CAVE and CAPE routines as well as the new subroutines.

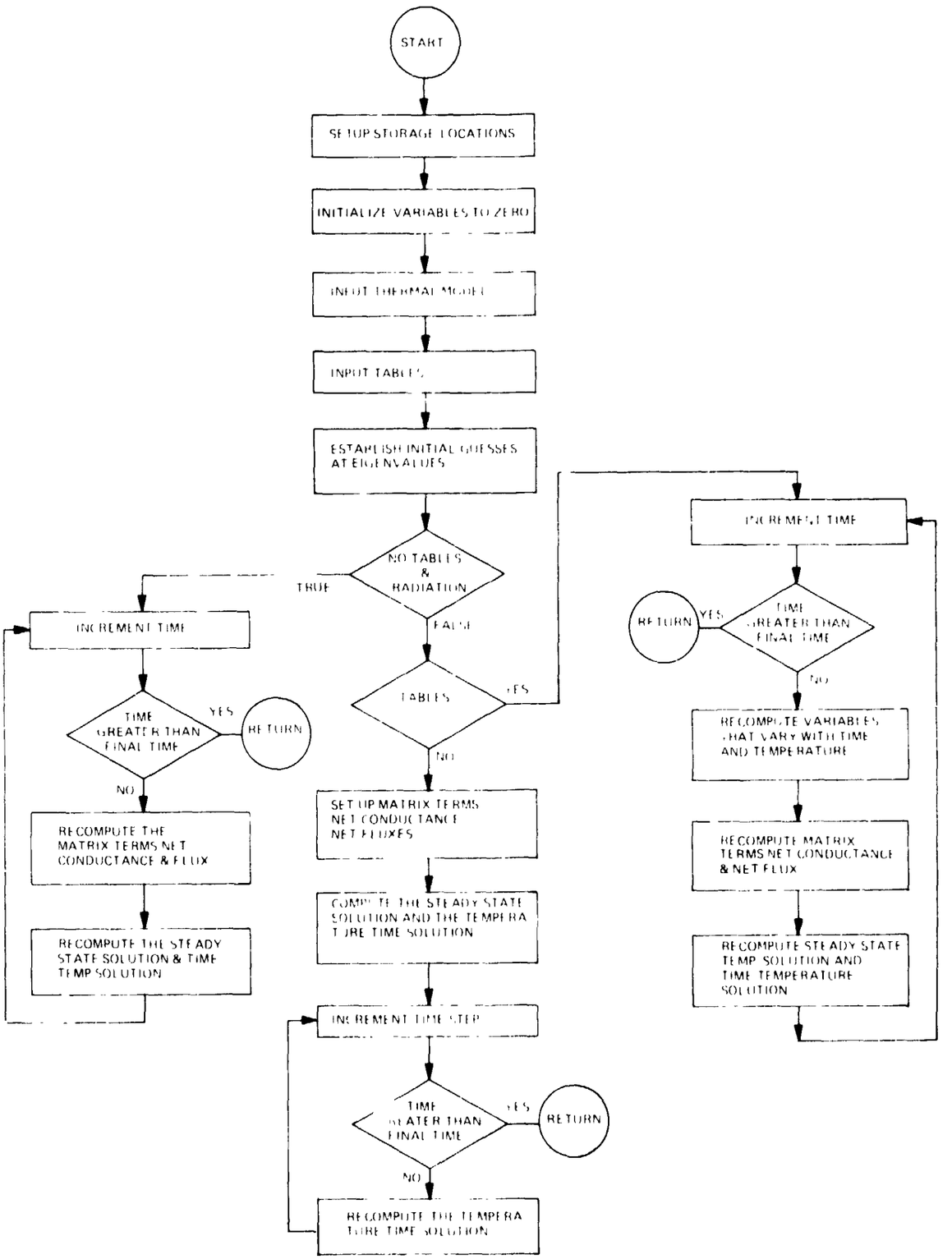


Figure 6-1. Simplified Flow of Logic in CAVE3

Table 6-1. Subroutine Descriptions

Routine	Description
CAVE	Main routine - Sets up storage array and dynamically allocate core storage to match the input requirements.
AORDER	Orders a set of real numbers.
BIJEN	Obtains dominant eigenvectors and eigenvalues of a given matrix (using Jennings Method of simultaneous vector iteration).
SWITCH	Utility routine to convert columns of a matrix to rows or vice versa.
SCAPR2	Computes scalar product of two vectors.
CAVE3	Establishes the main flow of the program.
CINIT	Initializes variables to zero.
DSCT	Computes the steady state and time dependent solutions.
DISPLA	Prints scalars, vectors, rectangular matrices, packed symmetric matrices and Hessenburg matrices.
EVECGS	Prepares approximate guesses for the eigenvectors.
LLTRAN	Cholesky decomposition of a positive definite symmetric matrix.
ORNML	Carries out the standard Gram-Schmidt orthonormalization of a group of vectors.
RVORDR	Reorders estimated eigenvalues according to magnitude.
SETUP	Establishes the CONNET and BFLUX arrays which are the matrix diagonal terms the net conductance and net flux terms respectively.
XTABS	Table read-in routine.
XINTP	Finds values of several dependent variables from a table by linear interpolation on a single independent variable.
TABLE	Determines which variables are changing and calls the appropriate tables to compute the result. Changes the COND, CAP, Q and T arrays as required.
TRISLV	Solution of a system of N linear equations using the Cholesky factor.
XREDE	Input routine.

Table 6-2. Variable List

The following is an alphabetical listing of the principle program variables and their definitions. Most are stored in COMMON. Other variables are used as indices, counters, or intermediate storage locations; but their functions may easily be determined from an inspection of the program listing. Input variables are indicated by the letter "I". Array names show their dimensions.

BFLUX (NUMTOT)		Net Flux of each node including heat sources and boundary conductance times boundary temperature.
BUFF (20)	I	Buffer region for listing of title cards.
CAP (NUMTOT)	I	Thermal capacitance. Subscript is node numbers. Inputted as mass x specific heat, stored as $1/\sqrt{(\text{mass x specific heat})}$
COND (NUMCON)	I	Thermal conductance. Subscript is conductance number (UA)
CONNET (NUMTOT)		Net conductance of each node.
CP1 (NUMITR)		Storage location for previously computed value of CAP (N) used for readjusting CAP (N) when properties change.
DTIME	I	Time step
DUM		Input buffer and intermediate storage in several areas
EVAL (NEVALV)		eigenvalues
EVEC (NUMITR, NEVALV)		eigenvector
FCT (50)		Table look-up return
FTIME	I	End computing time
IDIAG	I	Diagnostic Flag
IFLUX	I	Flux output flag
II	I	"Limit" for multiple parameter input (see input data discussion Section)

Table 6-2. Variable List (Cont'd)

IJ2 (NUMTOT)	I	Table of subscripted node representing variable physical property
JJ	I	"Spacing" for multiple parameter input (see input data discussion Section)
KNBN		Number of boundary nodes
KNIN		Number of iterated nodes and boundary nodes
KNQ		Number of heat sources
KODE	I	Program control parameter
LFLAG (50)	I	Table flag indicating type of table
L1 (50)	I	Number of values of independent variable in a table. Subscript is table number
L2 (50)	I	Number of dependent variables in a table. Subscript is table number.
MAXB		Total number of nodes iterated and boundary
MAXT		Total number of iterated nodes
N3		N4 + N5
N4		Number of conductances
N5		Number of radiation couplings
NCOND (2, NUMCON)	I	List of nodes connected by conductors. First subscript reserves room for two nodes. Second subscript is conductor number
NEVALU	I	Number of eigenvalues to be used.
NIN (NUMITR)		List of node numbers of iterated nodes
NLAST (50)		Position of independent variable in STG array from previous table look-up. Subscript is table number
NMAXB		High node number of boundary nodes

Table 6-2. Variable List (Cont'd)

NMTRIC	I	Flag indicating units of input
NODE (NUMNOD)		Array containing node position in NIN array as function of node label
NPOS (50)		Position of variable list for table in STG array. Subscript is table number
NQ (NUMFLX)	I	List of nodes to which heat sources are applied. Subscript is source number
NRAD (2, NUMRAD)	I	List of nodes connected by radiation couplings. First subscript reserves space for two nodes. Second subscript is radiation coupling number
NSTR	I	Reserve Storage words
NTABS (50)		Number of tables
Q (NUMFLX)	I	Heat source. Subscript is source number
NUMBND	I	Number of boundary nodes
NUMCON	I	Number of conductances
NUMNOD	I	Number of highest nodes
NUMFLX	I	Number of fluxes
NUMITR	I	Number of iterated nodes
NUMRAD	I	Number of radiations
NUMSCR	I	Storage variables
NUMTOT		Number of iterated and boundary nodes
Q1 (NUMCON)		Heat flux from node to each adjacent nodes, accumulated over each time
SIG	I	Stephen-Boltzmann constant
STG (5000)	I	Independent and dependent table variables
T (NUMTOT)	I	Temperature of interated and boundary nodes. Subscript is node number

Table 6-2. Variable List (Cont'd)

TIME	I	Time
TSS (NUMITR)		Steady State Temperature array
XK1 (NUMITR)		Initial value of conductivity
XNOD (NUMCON)		Conductance Constant $A/\Delta X$ in x direction
YNOD (NUMCON)		Conductance Constant $A/\Delta X$ in y direction

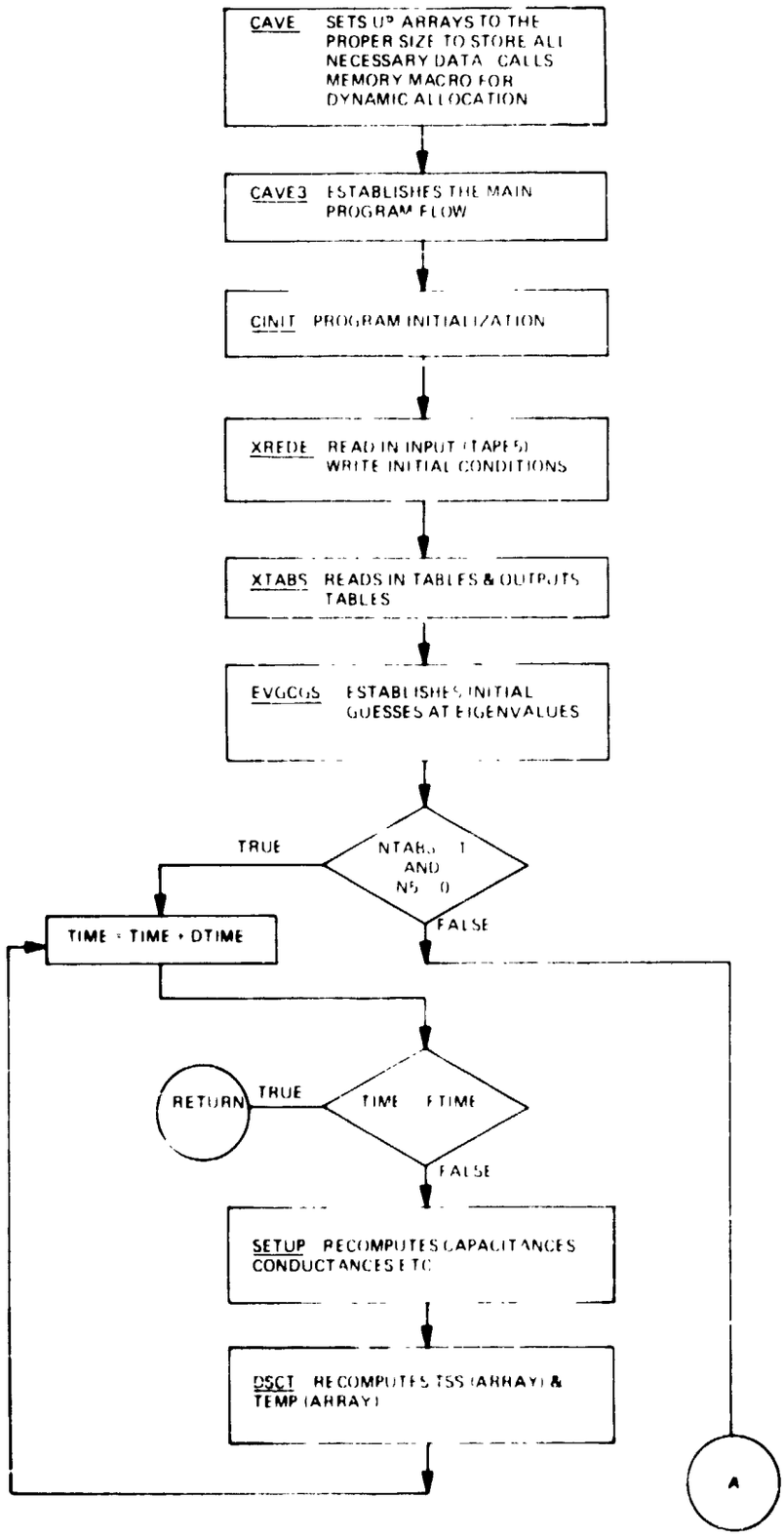


Figure 6-2. Organization of CAVE3 in Terms of the More Important Subroutine Calls (Sheet 1 of 2)

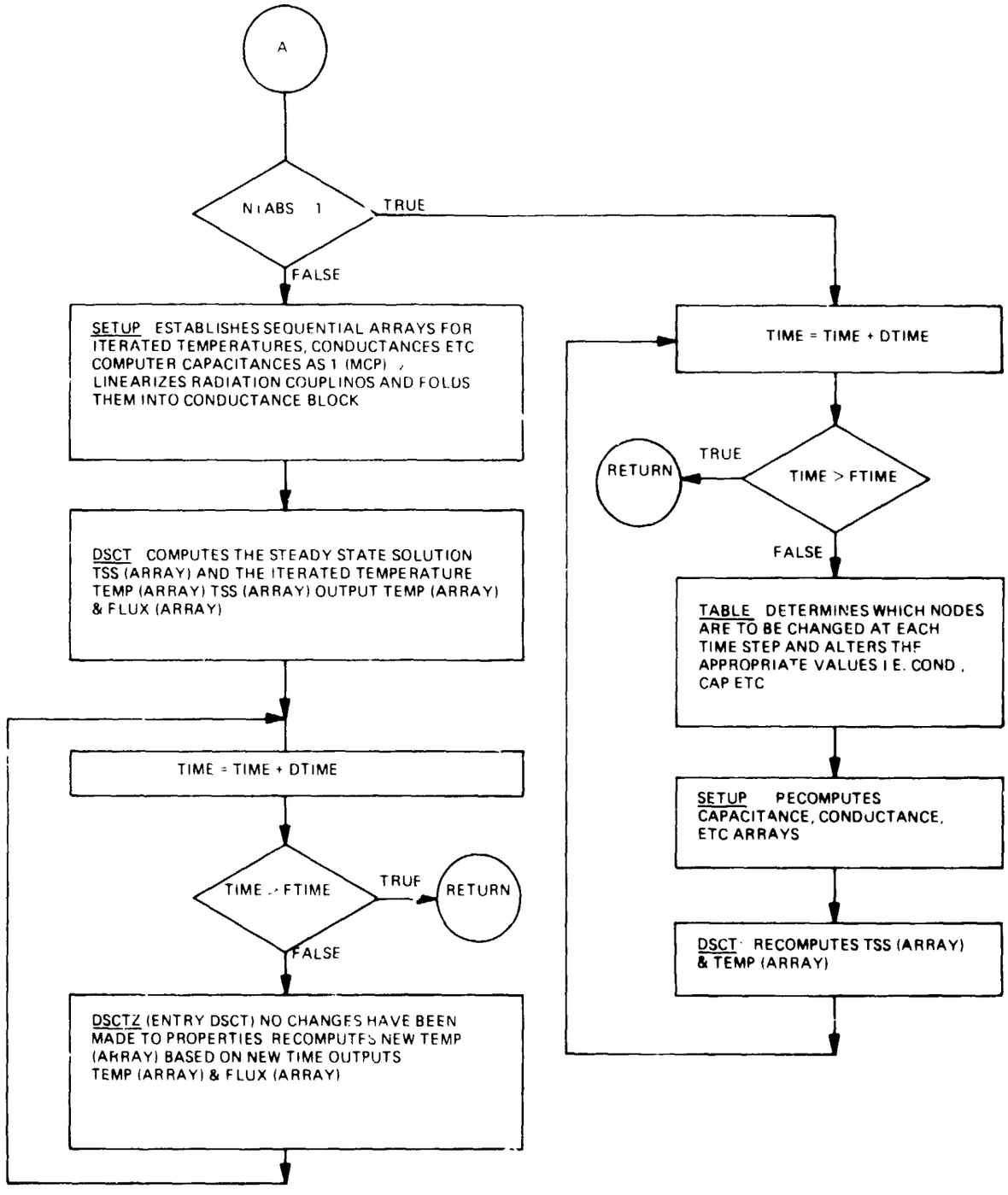


Figure 6-2. Organization of CAVE3 in Terms of the More Important Subroutine Calls (Sheet 2 of 2)

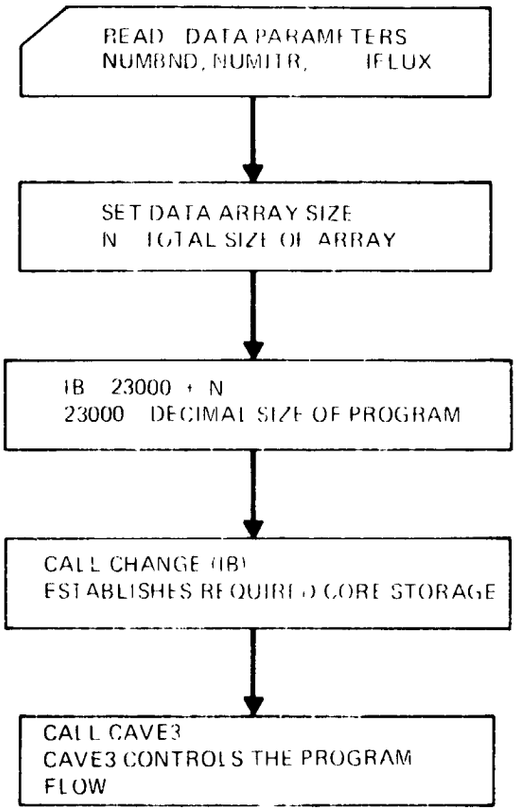


Figure 6-3. Main Routine Flow Chart

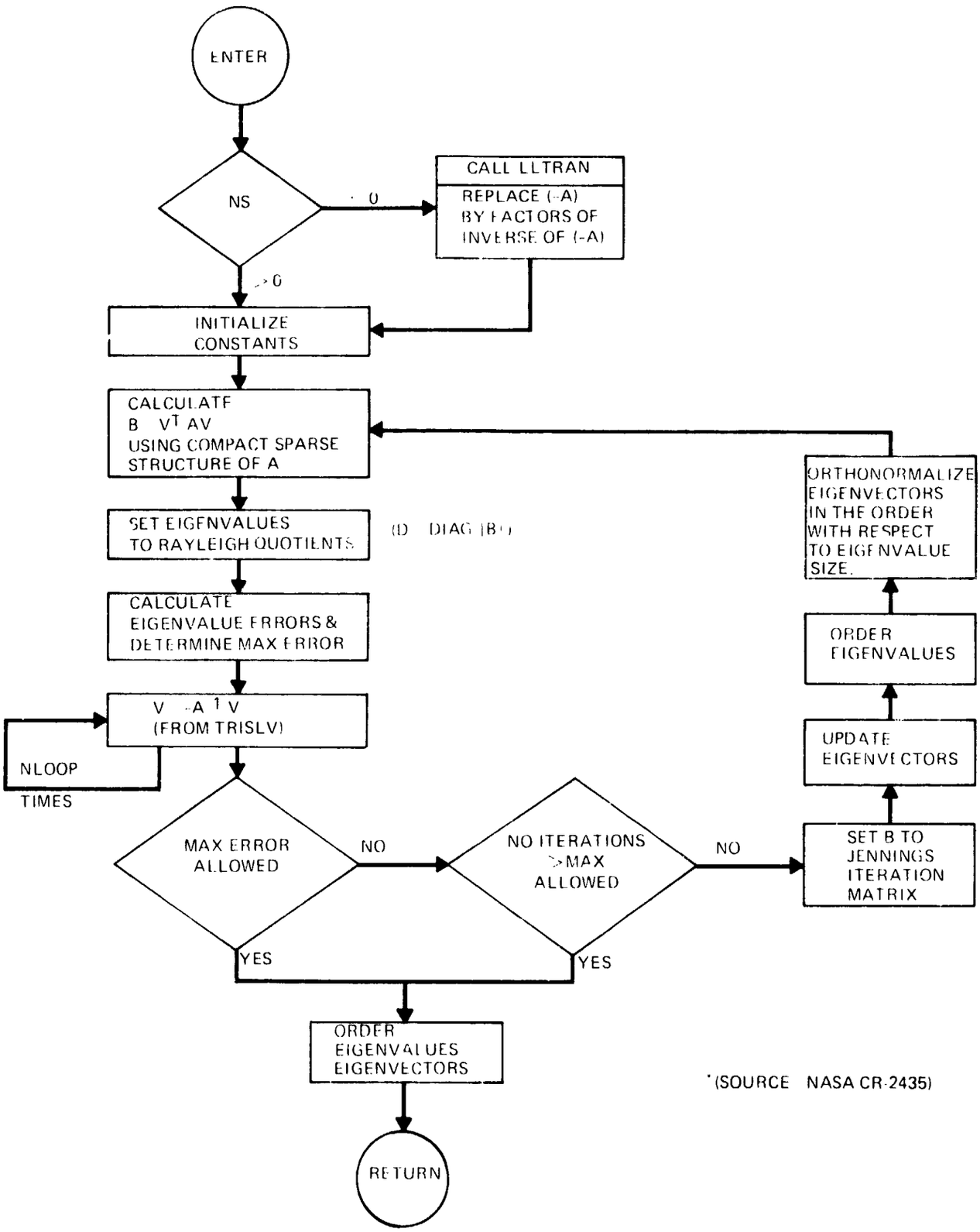
PURPOSE: ORDER A SET OF REAL NUMBERS

CALLING SEQUENCE: CALL AORDER (A, N, IPERM)

	NAME	DIMENSION	DESCRIPTION
INPUT	A	A(N)	ELEMENTS TO BE ORDERED
	N		NUMBER OF ELEMENTS = I N I N > 0 INCREASING ORDER N < 0 DECREASING ORDER
OUTPUT	IPERM	IPERM(N)	ORDER VECTOR - SPECIFIES THE SEQUENCE OF ELEMENT INDEX NUMBERS WHICH WILL PRESENT A AS AN ORDERED SET, i.e. DO 100 I = 1, N 100 WRITE (6, 1) A (IPERM(I)) 1 FORMAT (F 10.5) WILL LIST A AS AN ORDERED ARRAY

AORDER CALLS NO OTHER SUBROUTINES

Figure 6-4. Subroutine AORDER Description
(From NASA CR-2435)



*(SOURCE NASA CR-2435)

Figure 6-5. Subroutine BIJEN Flow Chart*

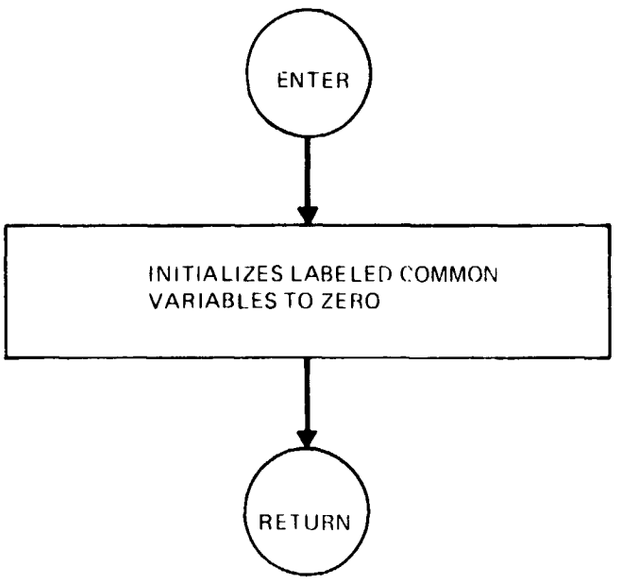


Figure 6-6. Subroutine CINIT Flow Chart

TITLE: DISPLA - Prints scalars, vectors, rectangular matrices, packed symmetric matrices, and Hessenberg matrices.

AUTHOR: M.J. Rossi

DATE. September 1973

APPLICABLE COMPUTERS: IBM 360/370, CDC 6000 SERIES

SOURCE LANGUAGE: FORTRAN IV

PURPOSE: To simplify printing of mathematical types of data structures in an easily read format which allows titles and index labels

METHOD: FORTRAN looping and write statements which indexes and addresses arrays according to their type.

USAGE: Call DISPLA (X, NFILE, TITLE, KAR, KIND, NROWS, NCOLS, MID).

X - Input - Array of one or more values to be printed
NFILE - Input - FORTRAN unit for printing
TITLE - Input - Vector of KAR characters used as title.
KAR - Input - Number of characters in above string
KIND - Input - Type of mathematical data structure.
= 0 scalar (or vector printed on one line with no index)
1 vector of |NROWS| elements, indexed
= 2 Rectangular |NROWS| by NCOLS matrix - Dimension (MID, *)
= 3 Packed Symmetric matrix of order |NROWS|

$$-\begin{bmatrix} 1 & 2 & 4 \\ 2 & 3 & 5 \\ 4 & 5 & 6 \end{bmatrix}$$ - lower triangular partial rows if NROWS positive

$$-\begin{bmatrix} 1 & 2 & 3 \\ 2 & 4 & 5 \\ 3 & 5 & 6 \end{bmatrix}$$ - lower triangular partial columns if NROWS negative

= 4 - Transposed Hessenberg matrix of order NROWS - Dimension (MID, MID)

NROWS - Input - Number of elements if KIND = 0 or 1
- Number of rows if KIND = 2
- Matrix order if KIND = 3 or 4
NCOLS - Input - Number of columns if KIND = 2
- Ignored otherwise
MID - Input - Matrix Dimension if KIND = 2 or 4
- Ignored otherwise

SUBROUTINE REQUIRED. SWITCH

Figure 6-7. Subroutine DISPLA Description
(From NASA CR-2435)

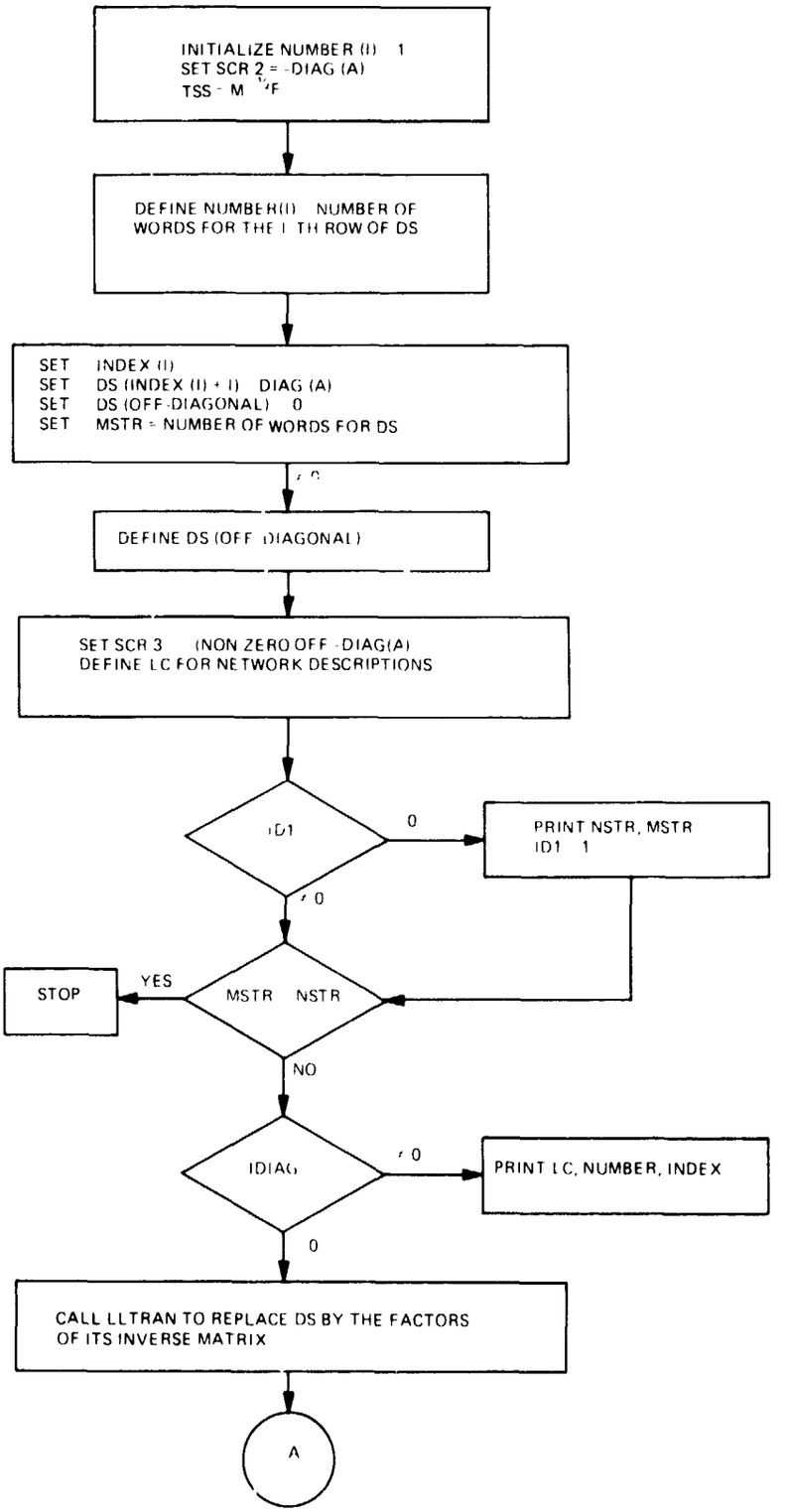


Figure 6-8. Subroutine DSCT Flow Chart (Sheet 1 of 2)

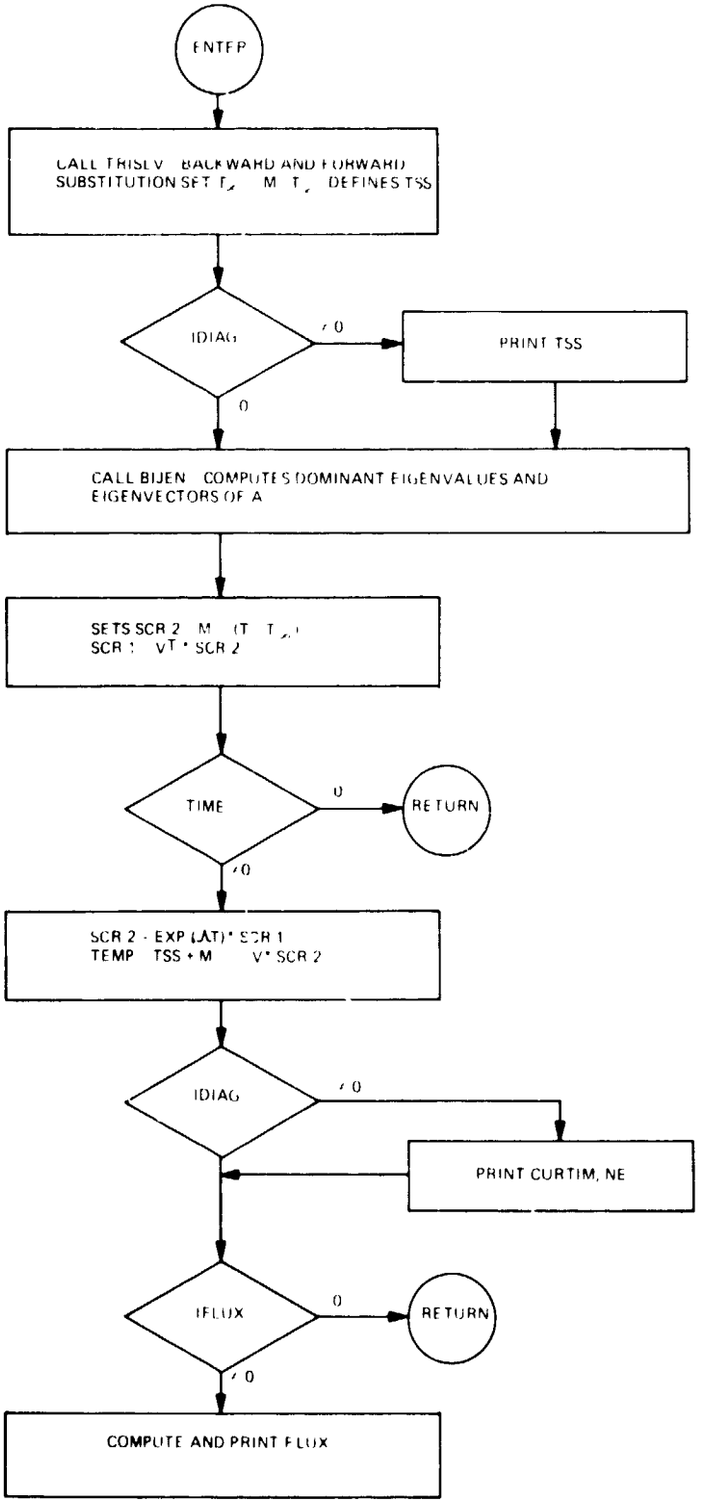


Figure 6-8. Subroutine DSCT Flow Chart (Sheet 2 of 2)

EVECGS computes guesses of the eigenvaules, eigenvectors and associated permutation index that are necessary to start the iteration in the Jennings method to calculate eigenvalues and eigenvectors. The formulae used for these guesses are:

ith eigenvalue $R \sim$ -1

ith eigenvector $A \approx e^{+y/(h/2)} \sin\left\{\frac{\pi}{2} + \pi\frac{x}{b}(i-1)\right\}$

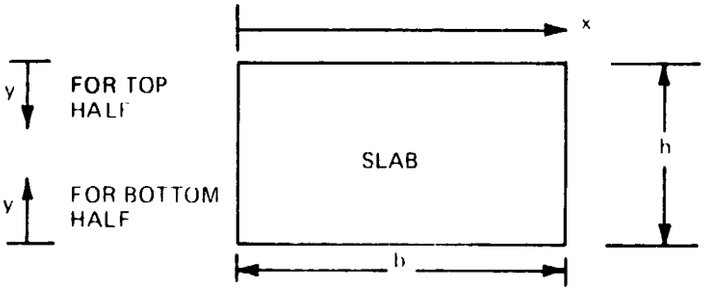


Figure 6-9. Subroutine EVECGS Description (From NASA CR-2435)

CHOLESKY DECOMPOSITION OF A POSITIVE DEFINITE SYMMETRIC MATRIX, OFTEN PRELIMINARY FOR LINEAR SYSTEM SOLUTION VIA SUBROUTINE TRISLV.

THE MATRIX IS STORED IN A ONE DIMENSIONAL ARRAY, A, IN A COMPACT WAY WHICH IS MOTIVATED BY THE PATTERN OF NONZERO ELEMENTS IN THE FACTOR.

THE MATRIX IS GIVEN ROW-WISE STARTING WITH THE FIRST NONZERO ELEMENT AND CONCLUDING WITH THE DIAGONAL ELEMENT INCLUDING INTERIOR ZEROS.

THE ARRAY NUMBER GIVES THE NUMBER OF ELEMENTS STORED FOR EACH ROW.

THE ARRAY KDIAG IS DEFINED BY THE ROUTINE TO BE THE INDEX OF DIAGONAL ELEMENTS OF THE MATRIX.

NSTR IS THE NUMBER OF WORDS NECESSARY FOR STORING THE MATRIX.

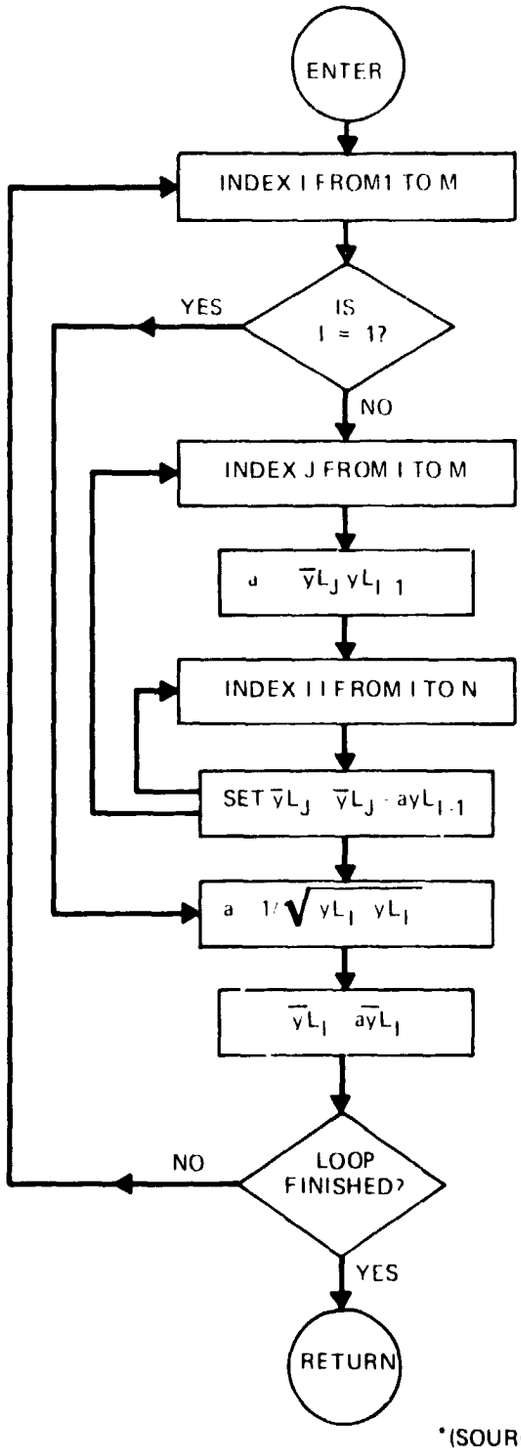
N IS THE ORDER OF THE MATRIX.

NIX IS SET BY THE ROUTINE AS ZERO NORMALLY, AND AS -I IF THE I-TH LEADING PRINCIPLE MINOR FAILS TO BE NUMERICALLY POSITIVE DEFINITE.

THE ARRAY A IS REDEFINED TO REPRESENT THE LOWER DIAGONAL CHOLESKY FACTOR. GENERALLY ALL KDIAG(N) ELEMENTS OF A WILL BE NON-ZERO ON OUTPUT, EVEN IF THERE ARE MANY INTERIOR ZEROS ON INPUT. THE PATTERN OF STORAGE IS ILLUSTRATED BY THE 6X6 CASE BELOW.

MATRIX							A(I,J)						NUMBER(I)
X	X	0	0	0	0		1						1
X	X	X	X	0	X		2	3					2
0	X	X	0	0	0	STORED IN THE ORDER	*	4	5				2
0	X	0	X	X	X		*	6	7	8			3
0	0	0	X	X	0		*	*	*	9	A		2
0	X	0	X	0	X		*	B	C	D	E	F	5

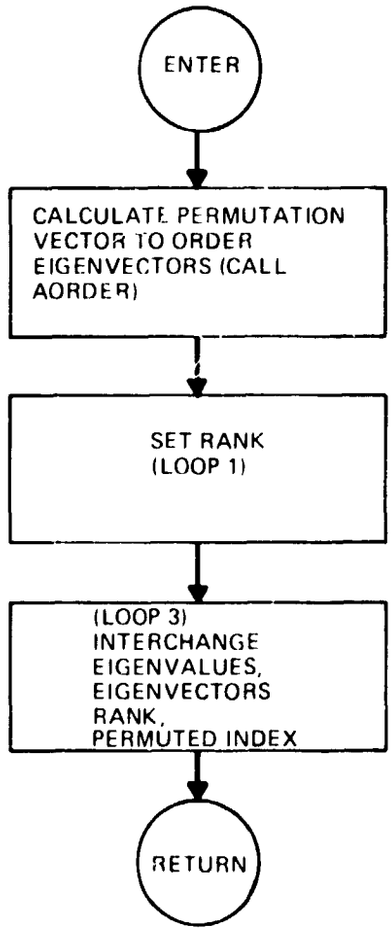
Figure 6-10. Subroutine LLTRAN Description



*(SOURCE: NASA CR-2435)

Figure 6-11. Subroutine ORNML Flow Chart*

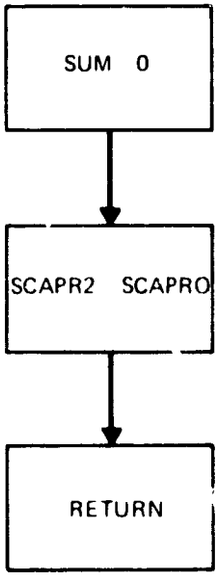
QUANTITY	SYMBOL	INPUT/OUTPUT	DIMENSION
EIGENVALUES	R	IN + OUT	R(MM)
EIGENVECTORS	V	IN + OUT	V(MID, MM)
RANK VECTOR	K	OUT	K(MM)
PERMUTATION VECTOR	L	OUT	L(MM)
EIGENVECTOR DIMENSION	N	IN	–
NUMBER OF EIGENVECTORS	MM	IN	–
DIMENSION OF ARRAY USED TO STORE EIGENVECTORS	MID	IN	–



*(SOURCE: NASA CR-2435)

Figure 6-12. Subroutine RVORDR Flow Chart*

SCAPR2 CALCULATES THE INNER
PRODUCT OF TWO VECTORS STORED
AS EQUALLY SPACED WORDS IN FORTRAN ARRAYS



*(SOURCE NASA CR 2435)

Figure 6-13. Subroutine SCAPR2 Flow Chart*

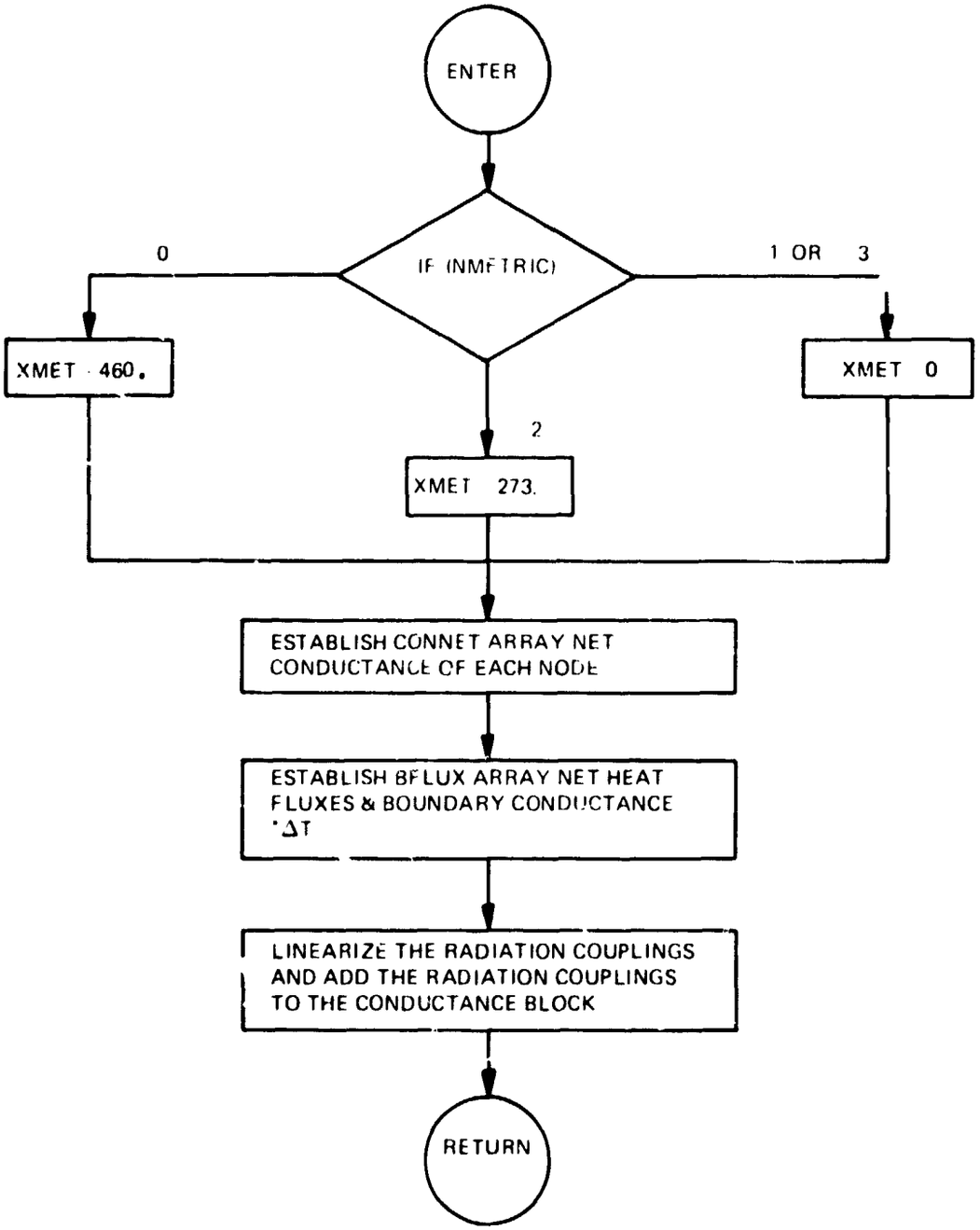


Figure 6-14. Subroutine SETUP Flow Chart

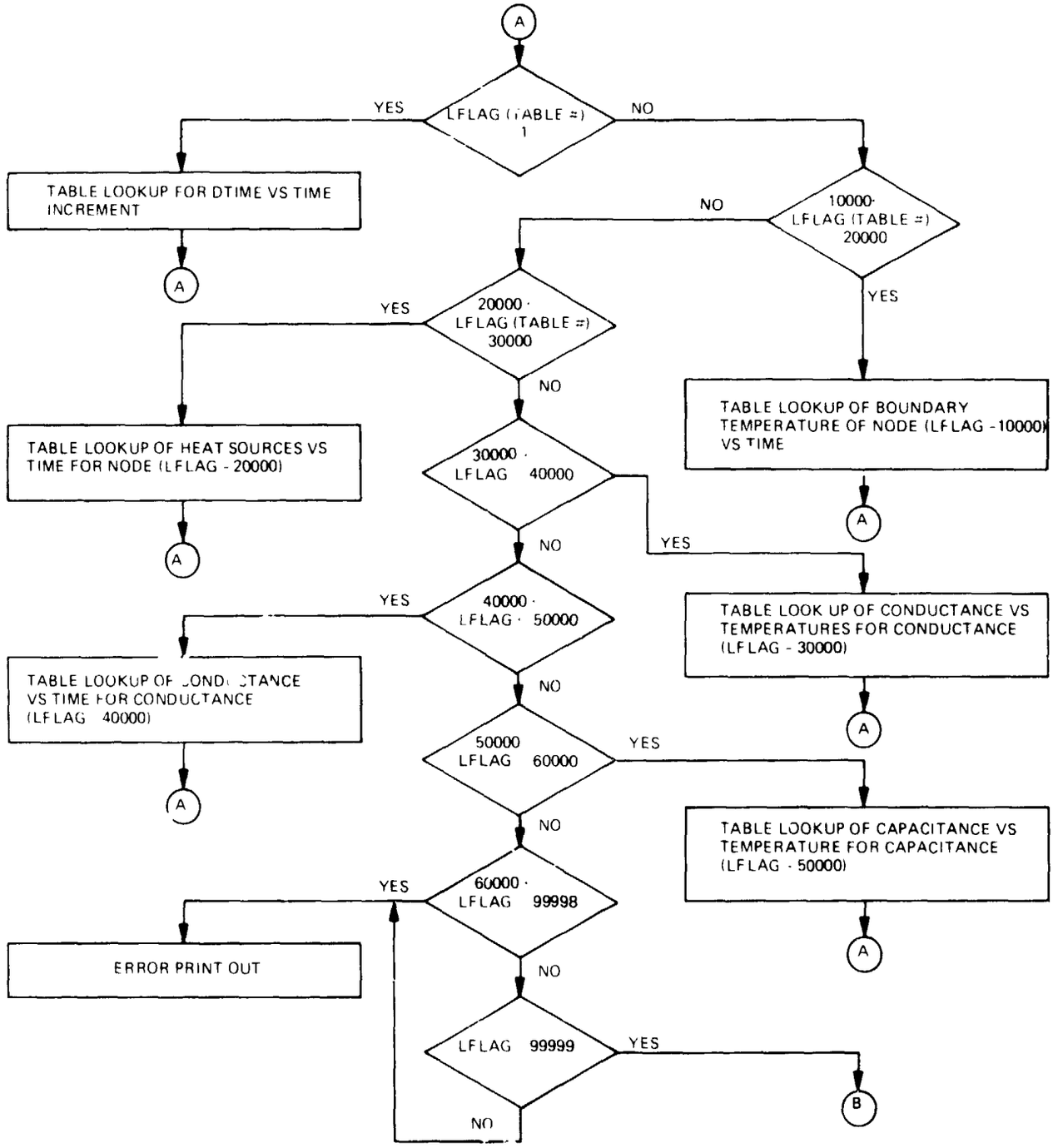


Figure 6-15. Subroutine TABLE Flow Chart (Sheet 1 of 2)

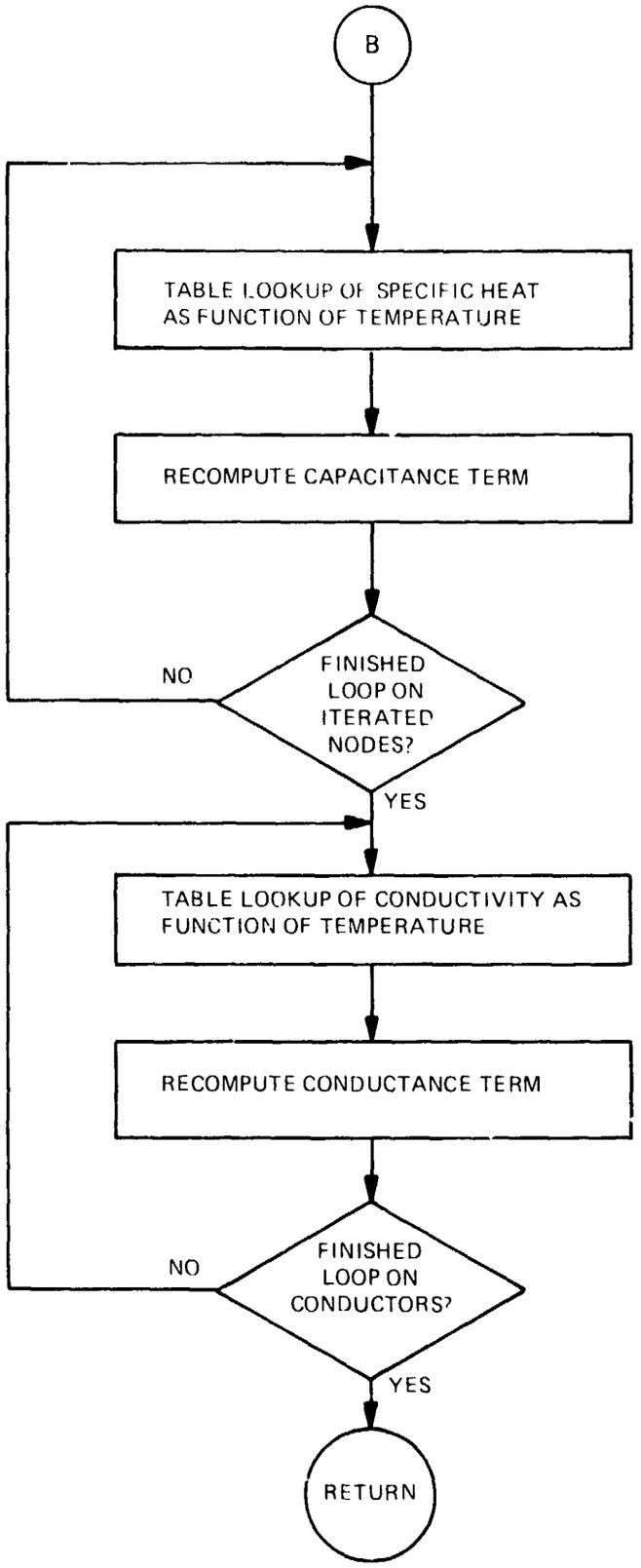


Figure 6-15. Subroutine TABLE Flow Chart (Sheet 2 of 2)

SOLUTION OF A SYSTEM OF N LINEAR EQUATIONS USING THE CHOLESKY FACTOR OFTEN COMPUTED BY SUBROUTINE LLTRAN. IN OTHER WORDS, THE COEFFICIENT MATRIX IS REPRESENTED AS THE PRODUCT OF A LOWER TRIANGULAR MATRIX TIMES ITS TRANSPOSE. THIS LOWER TRIANGULAR MATRIX IS SPECIFIED BY THE FORTRAN ARRAYS, A AND NUMBER. THE MATRIX IS STORED WITHOUT LEADING OR TRAILING ZEROS -- IN EACH ROW, DIAGONALS MUST BE NONZERO. THE PATTERN OF STORAGE IS ILLUSTRATED BY THE 6X6 CASE BELOW.

MATRIX							A(IJ)						NUMBER(I)
X	0	0	0	0	0		1						1
X	X	0	0	0	0		2	3					2
0	X	X	0	0	0	STORED IN THE ORDER	*	4	5				2
0	X	0	X	0	0		*	6	7	8			3
0	0	0	X	X	0		*	*	*	9	A		2
0	X	0	X	0	X		*	B	C	D	E	F	5

WHERE A THROUGH F DENOTE 10 THROUGH 15.

THE ROUTINE NEEDS TO BE TOLD THE NUMBER OF ELEMENTS STORED IN EACH ROW GIVEN BY THE ARRAY NUMBER. NSTR IS .GE. SUM NUMBER (I), I = 1, N) THE ROUTINE SOLVES THE M RIGHT HAND - SIDES A1 ONCE, II REPLACES THE RIGHT HAND SIDES BY THE CORRESPONDING SOLUTIONS. THE RIGHT HAND SIDES ARE STORED AS COLUMNS OF THE 2 DIMENSIONAL ARRAY, Y, DIMENSION TO MID BY M, WHERE MID, GE, N, THE ROUTINE ALSO CAN RECURSE NLOOP TIMES WHICH IS USEFUL IN SOME EIGENVECTOR CALCULATIONS.

Figure 6-16. Subroutine TRISLV Description

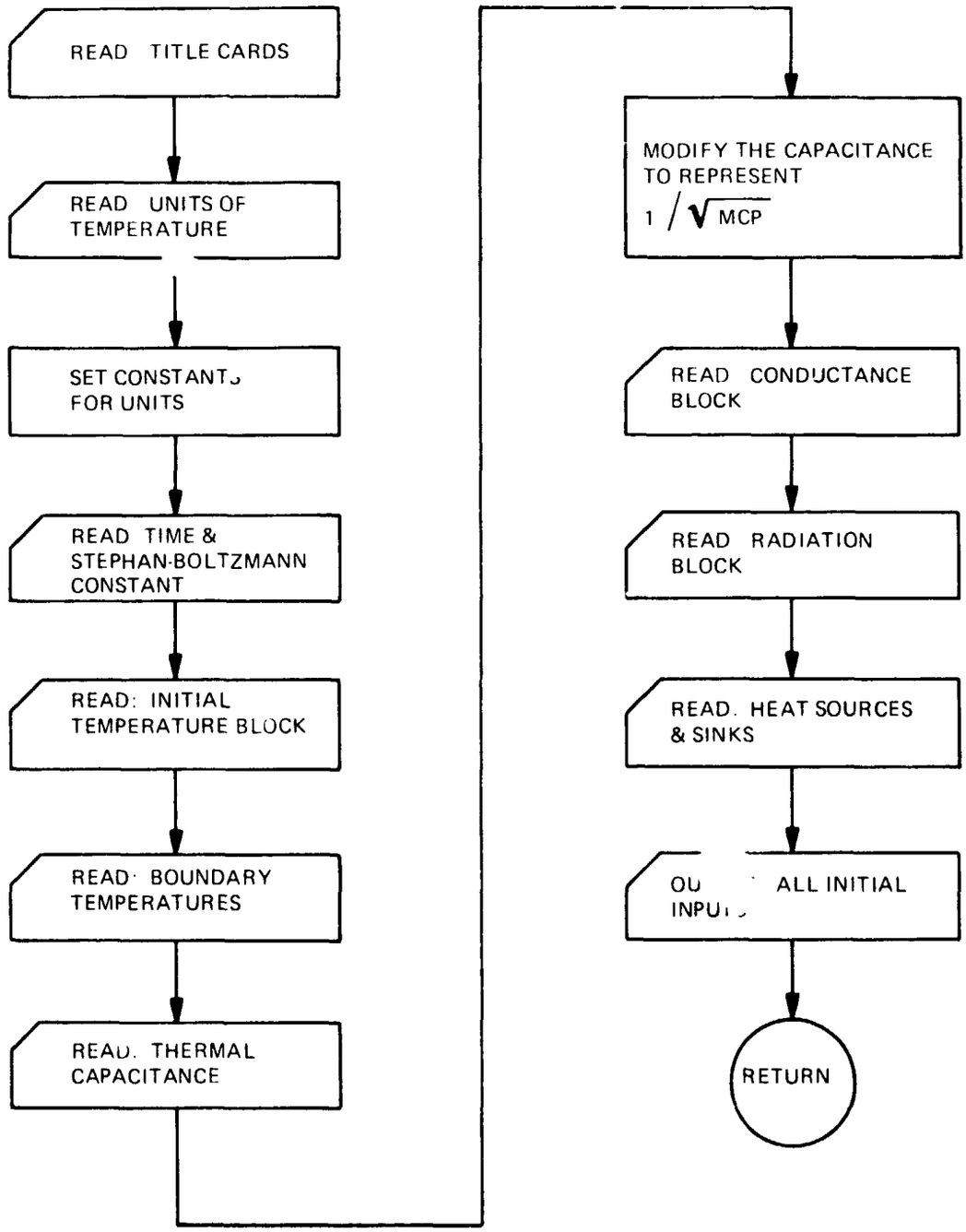


Figure 6-17. Subroutine XREDE Flow Chart

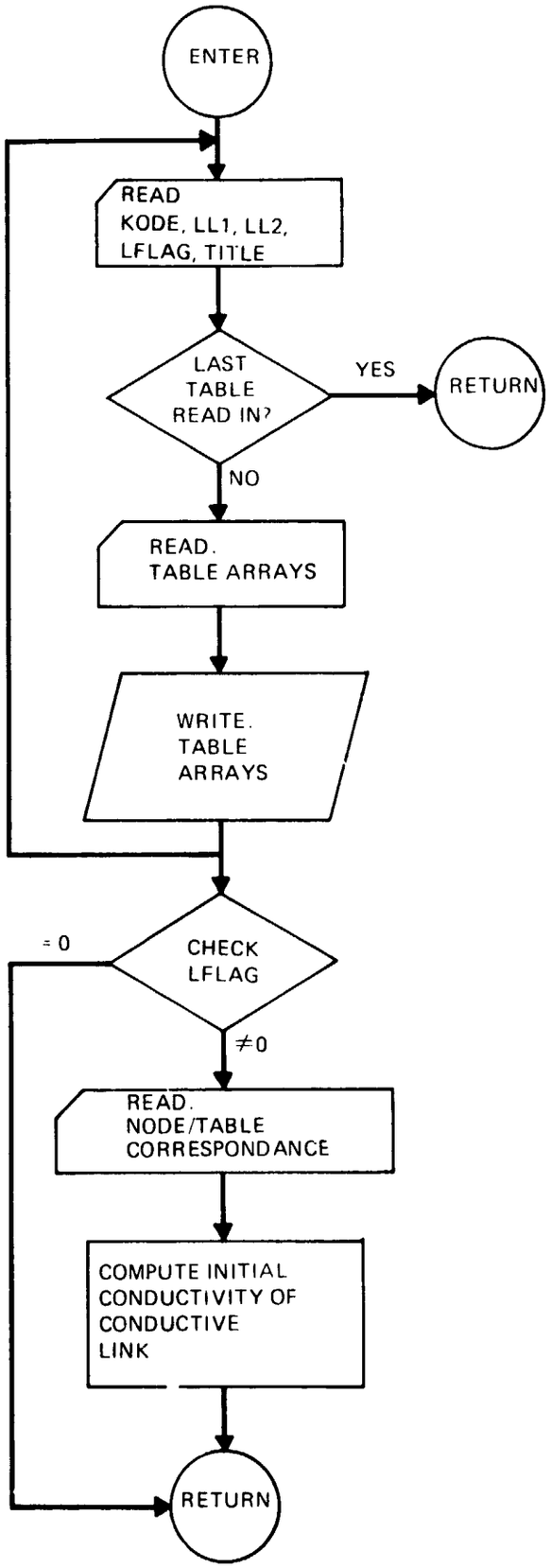


Figure 6-18. Subroutine XTABS Flow Chart

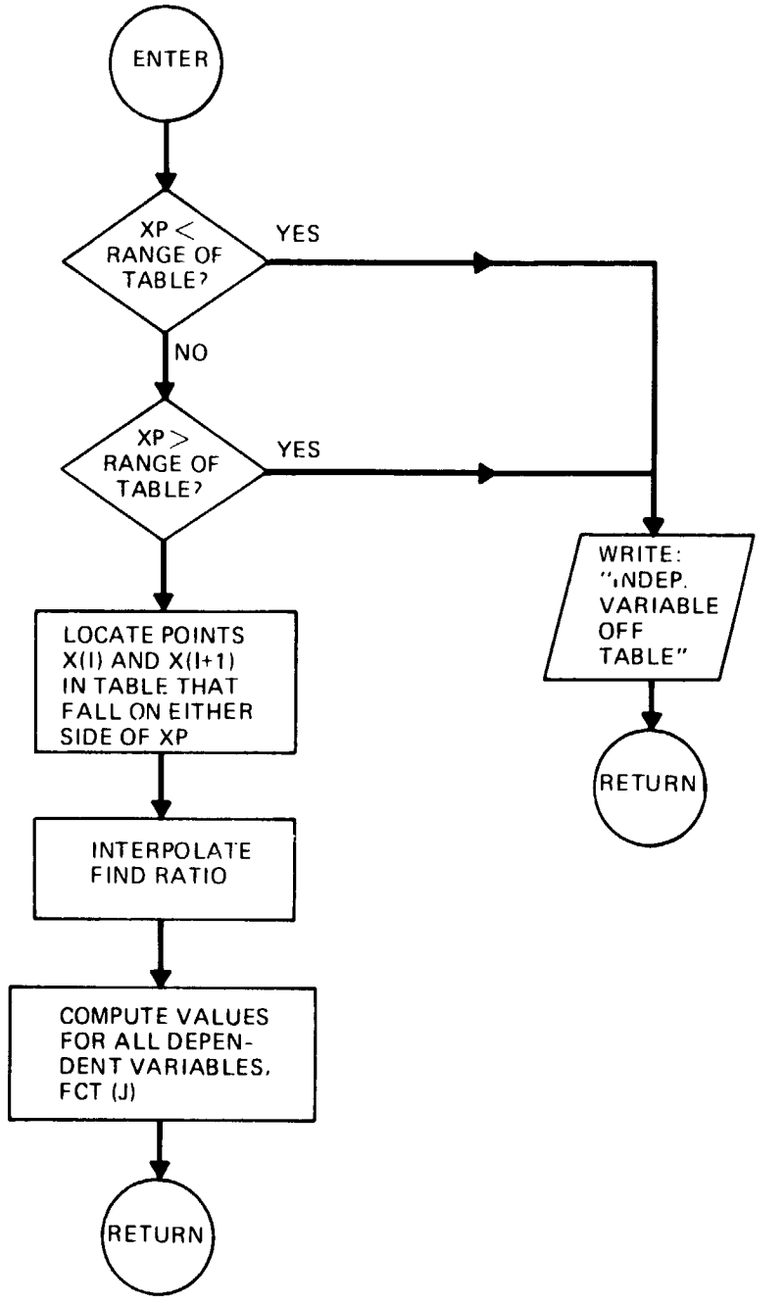


Figure 6-19. Subroutine XINTP Flow Chart

Section 7

REFERENCES

1. Rathjen, K. "CAVE, A Computer Code for Two-Dimensional Transient Heating Analysis of Conceptual Thermal Protection Systems for Hypersonic Vehicles" NASA CR-2897, 1977

2. Jennings, A., "A Direct Iteration Method of Obtaining Latent Roots and Vectors of a Symmetric Matrix", Proc. Cambridge Phil. Soc., 63, 1967, pp. 755-765